FUTURE MODEL FOR PEDIATRIC ICU (PICU) PATIENT ROOM: OPTIMIZE CARE IN TERMS OF PATIENT SAFETY AND STAFF EFFICIENCY BY DESIGN

A Thesis

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Master of Arts

by

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ABSTRACT

Objectives: This study is to identify the desired physical environment, amenities and spaces in multi-beds patient room in Pediatric Intensive Care Units that could support safe and speedy care delivery.

Study Design: This qualitative and quantitative case study is to 1) improve efficiency for care delivery by design (e.g., minimize steps Registered Nurses [RNs] take in delivering care); and 2) minimize the risk of HAIs (e.g., reduce contact transmissions).

Methods: A 35 hours observation was conducted in five consecutive weekdays in the PICU triple-patient rooms to record 13 RNs' work steps, walking paths, and high contact surfaces. In-person interviews with six of the observed nurses were conducted to understand their daily care delivery activities and opinions of the current and future patient room design.

Results: Opportunities to enhance RNs' work efficiency in the current multi-bed patient room are the spatial and amenities designs around the patient bedsides, the disposal area, and the preparation and supply closet. Four surfaces with high possibility of contact transmission are identified, including patient bedrails, IV pumps and poles, tubing and medical equipment around the bedside, and vital sign monitor screens.

Conclusions: Design recommendations are provided for improving efficiency by design via rethinking room layout, arrangement and amenities, and enhancing infection prevention by minimizing opportunities for contact transfer based on Lean and evidence-based design. Overall, the findings of this study will inform the future patient room design for Pediatric ICU.

BIOGRAPHICAL SKETCH

Yuqian Lu is from Beijing, the Republic of China. She graduated from Pratt Institute with a Bachelor of Fine Arts degree in Interior Architecture Design in 2016. After graduation, she was based in New York City as a full-time Interior Design Assistant for a year, until starting her Master of Arts program at College of Human Ecology School at Cornell University, where she majored in Interior Design with concentration in special population and minored in System Engineering. Her research focuses on healthcare research and design, service design, Lean thinking, and evidence-based practices.

She got Evidence-Based Design Accreditation and Certification (EDAC) and the International Council on Systems Engineering Associate Systems Engineering Professional (INCOSE ASEP) certifications during her master studies. She also got admitted presenting her thesis research in Environmental Design Research Association (EDRA) 2019 conference in Brooklyn, NY.

Yuqian received her Master of Arts degree in May 2019. After completing her master's degree, Yuqian will be relocated to New York City as a healthcare designer and focus on conducting research and providing evidence-based design recommendations and guidelines of the healthcare environment.

Dedicated to my parents, for their encouragement, support, and love.

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- Bishop, Naomi B. MD, Assistant Professor, Pediatric Critical Care Medicine, Director, Pediatric Critical Care Medicine, Quality and Performance Improvement
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CHAPTER 1

INTRODUCTION

The U.S. spends one-fifth of its economy on health care with higher expenses per capita is much more than any other nation, but outcomes are lag behind other developed countries (Centers for Medicare and Medicaid Services, 2014). This outcome may be because about 50% of the healthcare expenses, $765 billion, is wasted annually in the U.S. (McGinnis, 2013). Examples of such annual losses are $130 billion loss in inefficiently delivered services (operational inefficiencies at care delivery sites, medical errors, etc.), and $10 billion waste from Hospital-acquired-infections (HAIs) (McGinnis, 2013). These financial waste point to a major problem and an opportunity for the healthcare industry to reduce costs and improve outcomes in terms of patient safety, work efficiency and quality.

The care deliverers who work in the Pediatric Intensive Care Unit (PICU) are specialists within a specialty (Bratt, Broome, Kelber & Lostocco, 2000). They provide care to sick children, one of society's most vulnerable populations. That means care deliverers in the PICU face large work-loads and high levels of challenges of meeting the complex needs of critically ill children every day. Thus, it is critical for PICUs to optimize nurses' workflow to improve patient safety in the patient room, where most of the care delivery work happens.

The physical environment in hospitals has been identified as one main factor that could facilitate workflow and reduce the risks of HAIs acquisition (Pati, Harvey &

Thurston, 2012; Zimring, Jacob, Denham, Kamerow, Hall, Cowan, Kasli, Lenfestey, Do & Steinberg, 2013). Studies have indicated that excessive walking and unnecessary journeys are two contributors to nonproductive and inefficient care delivery in hospitals (Pati, Harvey & Thurston, 2012). These are caused mainly by inefficient physical space layout (Pati, Harvey & Thurston, 2012). Research has also found that various environmental factors could reduce contact transmission, thus minimizing the acquisition of healthcare-acquired-infections (HAI), such as implementing single-patient rooms, antimicrobial curtains, etc. Optimizing the staff's workflow by enhancing the built environment could reduce HCWs' contact frequencies with physical elements, and thus contribute to the decrease of the pathogen transmission.

1.1 Built Environment & HAIs

1.1.1 HAIs Background

Hospital-acquired infections (HAIs) remain one of the most common and major issues affecting patient safety, increasing unnecessary deaths and extending the length of hospital stays (Bastani, Abadi, & Haghani, 2015). Patients admitted to intensive care units (ICUs) face an increased risk greater than 20% of acquiring on infections from pathogens that are resident in the clinical environment (Wenzel, Thompson, Landry, Russell, Miller, de Leon & Miller, 1983). Besides, studies have shown that children admitted to PICUs have higher documented HAI acquisition rates than adult populations due to inherent risk factors such as undeveloped immune systems, underlying illness, or greater skin permeability (Yogaraj, Elward, & Fraser, 2002). Care delivery activities in healthcare environments involve frequent circulations around patients, equipment, furniture, and interior space, which create opportunities to transmit pathogens carried on healthcare workers' (HCWs) hands that increase the risk of HAIs.

1.1.2 Contact Transmission

Contact transmission, either direct or indirect, between HCWs or environmental components and vulnerable patients, is found the main cause of HAIs cause, though pathogens could be spread various other ways, such as through water and ventilation systems (Dicker, Coronado, Koo, & Parrish, 2006; Zimring et al., 2013). Surface moisture level and material in hospitals are critical to consider for reducing the contact transmission of pathogens, because the quality of the surface influences how long organisms can stay alive (Zimring et al., 2013).

Based on the conceptual transmission chain model (Figure 1-1), the built environment functions as the mediator of pathogens transmission through three pathways: the settings, the mediators, the facility elements (Steinberg, Ruck, Gleiber, Garzio, Cope, Bernard, Stmmerjohn, Schofield, Quetin & Ross, 2015). Environmental settings refer to the room layout and arrangement, such as single-patient rooms and patient curtain separations. A study found that by altering an intensive care unit from multi-bed to single-bed rooms, patients' infection rates fell 40% and this change was associated with a 10% shorter length of stay (Pennington & Isles, 2013). Therefore, optimizing the setting can spatially isolate patient to decrease pathogen spread and cross-transmission (Steinberg et al., 2015).

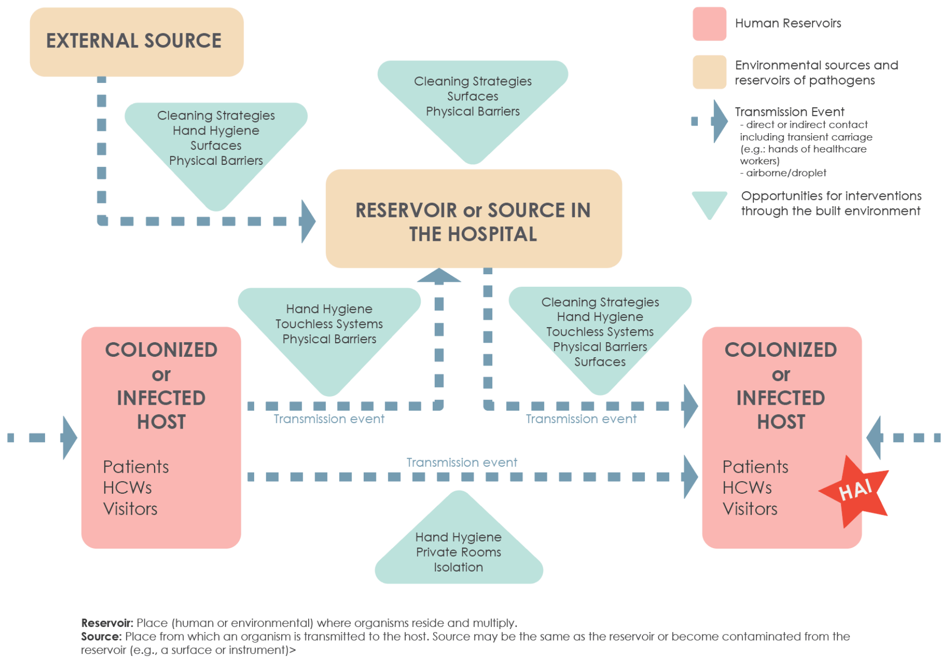


Figure 1-1 Conceptual HAI transmission chain (Steinberg et al., 2013)

Additionally, physical elements which include all the consistently contacted surfaces and floor areas can contribute to the transmission of HAIs as well (Salgado, Steuer, Troncoso & Collins, 2013). A study found that many sites locate closed to patient activity areas or often touched by people's hands are associated with an increase in microbial contamination (Dancer, White, Lamb, Girvan & Robertson, 2009). In addition, by using a quantitative approach, a study observed the interactions between HCWs and patients to identify frequently contacted surfaces in five intensive care units in a hospital (Huslage, Rutala, Sickbert-Bennett & Weber, 2010). This study finally defined five high-contact surfaces, including "the bed rails, the bed surface, the supply cart, the over-bed table, and the intravenous pump" (Huslage et al., 2010). Based on the HAI transmission chain, high-contacted patient care items and environmental surfaces play one of the most important parts of transmitting microbial pathogens causing HAIs (Cobrado, Silva-Dias, Azevedo & Rodrigues, 2017). Several manual and automated surface cleaning strategies are currently used, for example, daily cleaning with liquid disinfectants and novel liquid application cloths or mops, the microbicidal effect of UV light, and applying antimicrobial surfaces (Cobrado et al., 2017). However, the authors also mentioned that there is a consideration about cost-effective, as well as the durability, resistance, and toxicity of the cleaning methods (Cobrado et al., 2017).

Hand hygiene, a mediator factor of microorganism contact transmission, has been recognized by multiple studies as an essential infection prevention measure in reducing HAIs (Boyce & Pittet, 2002; Pittet, Allegranzi, Sax, Dharan, Pessoa-Silva, Donaldson & Boyce, 2006). Studies examined and reviewed implementation of multiple hand-hygiene interventions in patient rooms, including "bedside alcohol-based, waterless hand-rub dispensers," and found that this method led to significant improvements in staff hand hygiene compliance, reductions of bacterial load, the occurrence of HAIs, and cross-contamination (Mathai, Allegranzi, Kilpatrick & Pittet, 2010; Bischoff, Reynolds, Sessler, Edmond & Wenzel, 2000). A "five moments for hand hygiene" diagram was generated according to the HCWs bedside care delivery workflow (Figure 1-2). The intention of implementing hand hygiene in these five specific moments is to break the transmission of the pathogens from donor surfaces to receptor surfaces (Sax, Allegranzi, Uckay, Larson, Boyce & Pittet, 2007). The "five moments of hand hygiene" designate primary time and space reference points for HCWs to effectively inhibit the spread of microbes during care delivery activities, including moments of "before patient contact, before aseptic task, after body fluid exposure risk, after patient contact, and after contact with patient surroundings" (Sax et al., 2007).

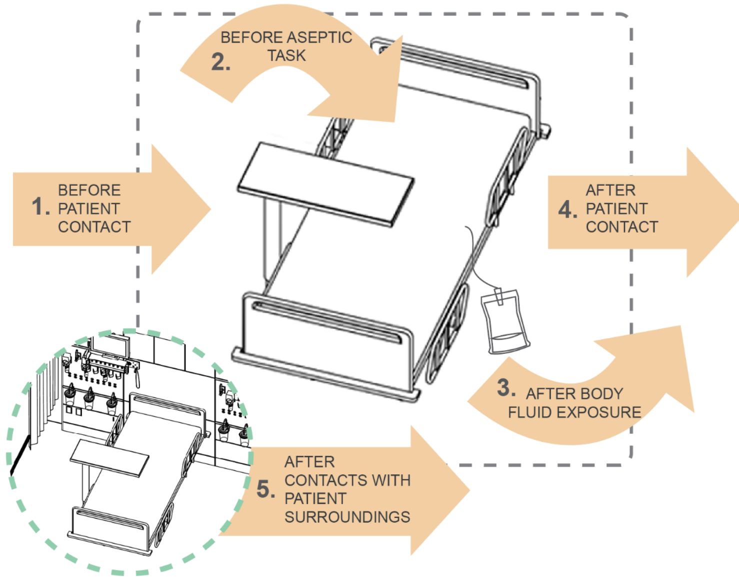


Figure 1-2 "Five moments for hand hygiene" (Sax et al., 2007).

1.2 Built Environment & Work Efficiency

Work efficiency for delivery of care in the patient rooms for the current study can be defined as "functional" efficiency, in other words, the movement required to complete a task (Pelletier & Thompson, 1960). RN's work efficiency has also been found to have a positive relationship to the level of care delivery quality and patient safety; in other words, higher work efficiency correlates with higher outcomes (Hendrich, Chow, Skierczynski, & Lu, 2008).

The built environment is recognized as one of the critical contributors to work efficiency and patient safety in healthcare environments. Empirical studies have proved that by changing the physical space and elements design, for example, increasing interior lighting level, providing acoustical material, and applying single-patient rooms could reduce physical interruptions to facilitate work efficiency (Ulrich et al., 2008).

Generate innovative work environment based on users' needs can alter HCWs' workflow and ultimately enhance staff's work efficiency. Many hospitals are planned without understanding HCWs' movement flows and resulted in spatial conflicts, which means the new facility design could not match and support HCWs' actual care delivery workflow (Ebright, Patterson, Chalko, & Render, 2003). A previous study identified eight work conflicts in hospitals after observing nurses daily work patterns in several intensive care units, including "disjointed supply sources, missing or nonfunctioning supplies and equipment, repetitive travel, interruptions, waiting for systems/processes, difficulty in accessing resources to continue care, breakdown in communication, and breakdowns in communication processes or mediums" (Ebright et al., 2003). These identified conflicts could increase wastes from interruptions, excessive walking, inconsistencies, and repetition (Ebright et al., 2003). Zadeh and colleagues (2012) used visual diagrams of space hierarchies to analyze the spatial conflicts and staff movement clutter in the main clinical space of a critical care unit. They suggested that the movement clutter illustrated in the diagram could be a reference source for designers to use while designing the space to reduce workflow wasted steps and optimize caregivers' movement sequences (Zadeh, Shepley & Waggener, 2012). Thus, applying user-centered analysis would enable the design of the healthcare space to achieve the goal of simplifying nurses' work complexity, eliminating unnecessary steps, and providing a much more efficient workflow and safer environment (Ebright et al., 2003). Overall, the design of the physical space in hospitals should base on the understanding and analysis of nurses' workflow and practices.

1.3 Workflow & HAIs

Healthcare design guidelines and infection control protocols focused heavily on providing solutions and regulations to improve staff work performance and to control HAIs acquisition rates, but infection prevention and care delivery efficiency in hospitals often remain ineffective (Hor, Hookr, Iedema, Wyer, Gilbert, Jorm & O'sullivan, 2017). As can be seen from previous sections, the physical environment has direct impacts on workflow and HAIs, but more importantly, the optimization of workflow can enhance infection prevention compliance through reducing contact transmission opportunities (Cohen, Carter, Pavia, Keenan, Jackson, Saiman & Larson, 2014; Hor et al., 2017; Son, Chuck, Childers, Usiak, Dowling, Andiel, Backer, Eagan & Sepkowitz, 2011).

The developed workflow maps offer opportunities to identify the flaws of the infection prevention system from human-factors and ergonomic standpoints. This can be done by observing and evaluating the interactions between the healthcare workers and their working system, such as the built environment, the medical equipment, the demands and the complicated care delivery activities (Anderson, Gosbee, Bessesen, & Williams, 2010). In other words, one can find high-frequency contact surfaces flaws induced by unnecessary walking (Anderson et al., 2010; Cohen et al., 2014).

Past studies had shown that infection prevention compliance and staff work efficiency are affected by the hospital spatial design and layout. Recognized environmental issues include "lack of defined dirty and clean areas, poor sink placement and design, [and] difficulties with movement around beds and other equipment" (Anderson, Gosbee, Bessesen & Williams, 2010). Similarly, Kumar and Storch (2004) illustrated workflow diagrams based on their observations and surveys with HCWs working processes and interactions with hand sanitizers. Several ideal locations for hand sanitizers on the workflow diagram were found, such as next to the patients and workstations, and between two patients (Kumar & Storch, 2004). The proposed locations, height, and size of the hand sanitizers could increase the using frequency but not interfere HCWs' spatial movement flow, which eventually could reduce contact transmission and excessive walking (Kumar & Storch, 2004). Another study found that the spatial design has a significant impact on preventing HAIs, especially cross-contamination, while studying HCWs infection prevention and control (IPC) routine in three wards in two hospitals (Hor et al., 2017). They conducted a qualitative study through approaches of interviews, observations and grounded theory based post-intervention in 24 weeks with a total of 177 HCWs. The result of the study showed that compared to hand hygiene and use of personal protective equipment (PPE), the logistical work of the morning rounding process, aseptic procedure, and especially the workflow of 'from clean to dirty' contributed more to the IPC (Hor et al., 2017). Based on the grounded theory, the authors concluded that transmission-prevention practice is a boundary work affected by the design of facilities and physical environment; and a "from clean to dirty" movement flow is an ideal solution to reduce contamination risks and improve efficiency (Hor et al., 2017).

Even though several studies addressed HAIs and workflow in healthcare environment from the optimization of physical space, this study applied evidence-based and human-centered approaches focusing on optimizing the workflow that could decrease contact transmissions in the PICU patient room, which no previous studies incorporated.

1.4 Lean

To address such complexities of both infection prevention and workflow improvement, a multidisciplinary and organized method would be necessary to support a systematic work environment. Lean, a system engineering method, is used to assist with analysis and generation of workflow diagrams to make transformational HAIs culture changes, foster continuous operational and administrative improvement, and drive out work waste in the workspace of PICU patient rooms (Liker, 2004).

1.4.1 Lean in Healthcare

Lean thinking started with the Toyota Production System in the 1950s (Womack & Jones, 1997). Though Lean was created by Toyota, for the industrial factory to use, researchers and architects have been combining Lean thinking into healthcare and this became a research trend since the early 2000s (Thompson, Wolf, & Spear, 2003). Because no matter what types of work, there always be waste to be removed and be needs to understand how to build quality into every step to better meet customers' needs. Additionally, the most critical attributes of Lean are understanding their clients, speaking their languages and designing spaces that support the optimal flow of value-added work (Serrano, Hegge, Sato, Richmond, & Stahnke, 2010).

The primary goal of Lean is to become aware of and eliminate waste in all processes. The original list of eight defects according to Liker's (2004) book Lean for Toyota include:

1) Waiting, which means the time we lose when we have to wait for the next event to occur or the next work activity, or when we must correct the thing that is done wrong, or when we have to travel.

2) Searching, which stands for searching for supplies, equipment or people.

3) Defects (e.g., an error, flaw, and disfunction), which means the time is spent on doing something incorrectly, and the uncorrected and undiscovered errors were passed to the end users.

4) Overproduction, which means producing more than the customer has ordered and more than what is currently needed.

5) Movement, which refers to an unnecessary action of the product in the system.

6) Inventory, which is about unnecessary supplies or raw materials in storage, unnecessary work in process or excessive inventory through ordering for "just in case."

7) Motion, which means the superfluous movement of equipment or people in ways that add strain to work.

8) Over-processing, which refers to the processes or procedures in the system that do not add value to the end users.

After identifying all the wastes in the system, using the Value Stream Map (VSM), one can outline all the working steps and procedures to identify wastes and help to eliminate the non-value steps (Serrano et al., 2010). A depiction of the current VSM flow and an understanding of the time it takes along the end users' journey are very useful, so it presents if improvements impact the overall lead time. The most valuable components of the VSM are the depictions of the Lead Time, Cycle Time and Wait Time components, the depiction of defects, and more importantly, the determination of which steps are value added or non-value added, shown in Figure 1-3 (Serrano et al., 2010).

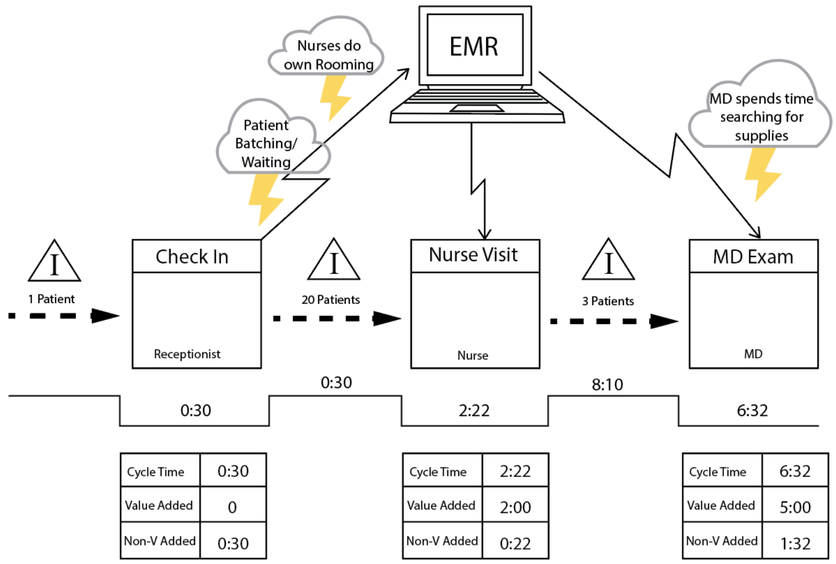


Figure 1-3 Value Stream Mapping. The clouds represent the defects in the process. Triangles represent inventory or wait time (Serrano et al., 2010).

Another major Lean tool developed is called "5 S": Sorting, Setting in order, Shine, Standardizing and Sustaining. This method is not an occasional activity, but a constant ongoing process to minimize system waste through improved visual management and organization (Serrano et al., 2010). By keeping the often-needed items stored in the most accessible location and returned to the correct location after use would enable the system to support a tidy and organized workplace system allowing users to work without excess inventories (Liker, 2004; Serrano et al., 2010).

Because of the thriving of the new area of research of Lean in healthcare, several published literature reviews analyzed the current and emerging trends of Lean application in healthcare and presented the effectiveness and necessity of applying Lean.

Poksinska (2010) not only provided evidence about how Lean is implemented in healthcare, but also illustrated barriers, challenges and consequences. D'Andreamatteo and colleagues (2015) published a literature review of Lean healthcare based on much broader research questions and different inclusion criterias compared to the previous ones. Their research presented the diffusion of Lean in healthcare, specifically about the trend of research topics for Lean in healthcare and the increased interest in medical and nursing journals of applying Lean in healthcare to improve efficiency, operational outcomes, and staff well-being (D'Andreamatteo, Ianni, Lega & Sargiacomo, 2015).

1.4.2 Lean in Facilitating Workflow and HAIs Protocol Compliance

Lean is becoming a popular tool for healthcare to use with human-centered environmental design to improve work efficiency and safety (Boaden, Harvey, Moxham & Proudlove, 2008; D'Andreamatteo et al., 2015). Previous studies have applied Lean thinking to several hospital units, including emergency department, operating room, acute care, pediatric intensive care unit, etc. (Cima, Brown, Hebl, Moore, Rogers, Kollengode…& Team, 2011; Mazzocato, Holden, Brommels, Aronsson, Bäckman, Elg & Thor, 2012; Vats, Goin, & Fortenberry, 2011; Zadeh et al., 2012).

Holden's review of Lean application in emergency department showed that Lean can not only reduce waiting times and length of stay, but the improvement of workflow is accompanied by improved patient outcomes, fewer medical errors, or more careful care delivery process (Holden, 2011). By further exploring Lean in the healthcare of how and why this intervention succeeded, Mazzocato and colleagues (2012) conducted a pre and post quasi-experiment single case study in a Swedish Pediatric Emergency

Department and collected quantitative data of waiting times before and after the Lean intervention. In addition, they conducted observations and interviews as well to describe the process and content of the Lean intervention, and finally claimed that by using Lean in the healthcare setting they showed a 5% improvement in waiting and lead time (Mazzocato et al., 2012). This was accomplished by Lean generated changes to work schedules, communication and coordination, workplace layout, and problem-solving methods. Moreover, their study concluded these changes could lead to efficiency improvement is because the standardized work schedule and environment could reduce ambiguity and encourage people interaction, provide one-piece workflow, and inspire staffs to investigate problems and participate in the decision-making process (Mazzocato et al., 2012). Similarly, Cima and colleagues (2011) also showed that employing Lean in hospital operating rooms could help to eliminate non-value-added steps and contribute to improvement in work efficiency through their pre and post studies. Along with the Value Stream Map used in the study that presented the entire surgical process with identified waiting time and wasted steps, the research team identified five work streams that could eliminate non-value-added steps to improve work efficiency (Cima et al., 2011). The five work streams included minimizing unplanned space capacity variation, standardizing the preoperative process, reducing nurses nonoperative time, eliminating redundant information, and increasing employee engagement (Cima et al., 2011). Researchers concluded that implementing Lean thinking to operation rooms could increase clinicians' work efficiency and improve the hospital's financial performance since wasted nonoperative time, staff overtime, and waiting time was saved (Cima et al., 2011).

Similarly, other studies used Lean to identify wastes and opportunities to improve physicians' morning rounding workflow in PICU (Vats et al., 2011). The study used Lean principles and tools, such as behavior mapping diagrams and value stream mapping, to not only visualize and illustrate the current physicians' work process and activities, but also identify sources of the non-value-added steps and operational and environmental wastes during the rounding process. Besides, the study included the standard work process and tasks during morning rounding practice to reduce the variability between the different personality of physicians (Vats et al., 2011). In this way, the proposed new valued-stream mapping of ideal rounding workflow became a consistent and patient-centered process with minimized wastes and presented a 42% deduction of working time (Vats et al., 2011).

Additionally, Lean was used to increase hand hygiene compliance in Intensive Care Units by optimizing the physical environment, education, and culture (Carboneau, Benge, Jaco, & Robinson, 2010; O'Reilly et al., 2016). O'Reilly and colleagues (2016) did not separate improving hand hygiene process from the complex work systems like the other studies; instead, they treated hand hygiene and entering room process as an integrated whole. Their study scope included "performing hand hygiene, donning contact precaution equipment, transporting material such as medications, central line supplies, etc., and greeting and communicating with patients and families" (O'Reilly et al., 2016). Then, the researchers illustrated the workflow process map followed the Lean 3P (Production Preparation Process) to design new patient room entry in a way that optimized hand hygiene compliance and staff work efficiency simultaneously (O'Reilly et al., 2016). Overall, previous studies claimed that the physical environment plays a key role in supporting infection prevention; thus, it is essential to consider developing the work process and the built environment at the same time. Based on the above foundation, the current study is an evaluation of the interior environment of a PICU with regard to improving efficiency and minimizing HAIs.

1.5 Scope of the Study

The present study is to identify the desired physical environment, amenities and spaces in the current PICU patient room to support safe and speedy care delivery by registered nurses. This study, therefore, has two focuses: 1) improve RNs' care delivery efficiency by reducing unnecessary steps and 2) improve safety through prevention of contact infection transmission.

The present study is based on existing research and theories explained above, and it is also a valuable contribution to the field, given the limited number of imperial studies applying these tools in pediatric ICU patient rooms. The published research summarized above explored improving infection prevention and workflow by using Lean or human-centered design approaches (O'Reilly et al.,2016; Vats et al., 2011, 2012, Cima et al., 2011), but none of them were conducted in PICU patient rooms. Trudel and colleagues (2018) conducted a qualitative study in an Australian Neonatal Intensive Care Units patient room (NICU) to identify the environmental threats to infection prevention. However, the NICU is in an Australia hospital, where they have different design principles, infection prevention guidelines and nurses' training, and the scope of the study did not include enhancing the RNs' workflow and work efficiency.

Therefore, this study fills the gap of enhancing the RNs' work efficiency and also identifying the contact transmission threats in the PICU patient rooms. Evidence-based and human-centered methods help the proposed design recommendations to meet future RNs' operational and functional needs while delivering care in the PICU patient rooms which would facilitate higher work efficiency and quality of care.

Two research questions of the study are:

1. How could the physical environment layout in the PICU patient room reduce RNs' wasted work steps?
2. How could the physical environment features in the PICU patient room improve infection control compliance in terms of reducing contact transmission infection?

CHAPTER 2

METHODS

2.1 Research Design

The purpose of this qualitative and quantitative mixed methods case study is to identify the desired physical environment, amenities and spaces in the PICU patient room to support safe and speedy care delivery by nurses. This study is an in-depth analysis of registered nurses' (RNs) bedside work processes in a Pediatric Intensive Care Unit (PICU). This study was approved by and conducted within the guidelines and rules of the Institutional Review Board (IRB Protocol #1808008183) for Human Participants from Cornell University (Appendix A) and Weill Cornell Medicine.

The current study has two aims: 1) promote efficiency by minimizing steps the RNs take in delivering care by making the room layout more efficient; 2) promote safety by minimizing the risk of infection transfer by contact transmission by identifying high touch areas in the room and identifying environmental and behavioral precautions. Overall, this study is expected to result in design recommendations and guidelines for the PICU to use for improving their current and future workspace in the patient room.

2.2 Site Selection

The study was conducted in a large metropolitan hospital in New York State with about 850 beds providing adult and pediatric diagnostic and treatment services. The hospital provides services and expertise for the full range of pediatric subspecialties.

The pediatric critical care unit (PICU) includes 23 beds, including three single-patient rooms, one double-patient room, and six triple-patient rooms treating 1200 patients on average per year. The triple-patient rooms are the most typical room layout in this PICU with three different typologies which are the focus of this study (Figure 2-1).

Analyzing a patient room, there are three zones in typical patient rooms: work, patient, and family zone. Given the scope of this study is work efficiency and safety, the work zone is the main focus of this study, including the preparation work zone and the bedside work zone. As shown in figure 2-1, in the typical triple-patient room, the preparation work zone is located at the upper right corner immediately adjacent to the patient room entrance and contains a two-persons nurse station with two computers, two chairs, a sink, a counter space, a supply storage closet, four trash bins and a small medication drawer. The area immediately surrounding the bed area (e.g., bedside work counter, equipment.) is the bedside work zone for RNs. The beside work zone contains all the medical equipment needed for the patient (vital sign, IV poles and monitor, respiration machine, etc.), buckets hung on the headwall to store supplies, and workstations on wheels (WOW) as needed.

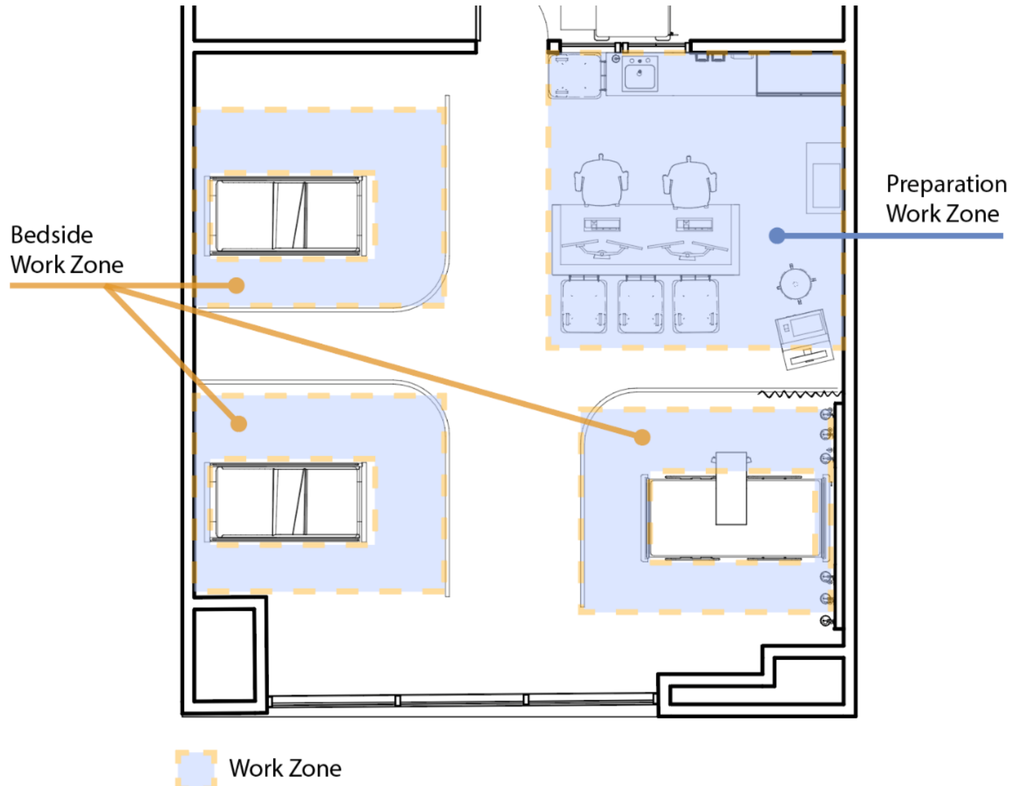


Figure 2-1 Triple-Patient Room Work Zone Diagram

2.3 Participants

The participants in this study are the registered nurses (RNs) working in the Pediatric intensive care unit in the hospital. 13 RNs included in this study (n=13), and six of the 13 RNs participated in the interview session. The participants' ages range from 18-65 and have served in the PICU for more than one month at the time of this study was performed. The sample of this study is the numbers of observations conducted in the patient room which is clustered by nurses' care delivery tasks. Before each research session, including interview and observation, the purpose and the process of this research project were introduced, and formal verbal consent was obtained from all participants. The interview time, observation dates and patient rooms were coordinated with those who agreed to participate with the permission of the unit leadership. This study is also fully anonymous.

2.4 Data Collection

The clinical director of the Pediatric Intensive Care Units supported and guided the researcher in the recruitment process. An announcement of the study was made through email and in a monthly staff meeting by the leadership to inform them of the research intentions and to solicit participation. The administrative and clinical leadership and staff especially nurses were involved since early on and provided input on the scope, direction and methods of this study. They continued to provide insights throughout the data collection and interpretation phase.

The objective was to capture the RNs' workflow and interactions with the physical environment of the patient room. Thus, observation and interview were used in the data collection phase. To be more specific, approaches include behavior mapping, clinical performance chart, 3D drawings, and semi-structured in-person interviews with RNs.

2.4.1 Observation

The researcher stationed at the corner of the patient room outside of the sterile patient zone with direct visual access to the entire room in order to conduct the unobtrusive observation. The RN's care delivery tasks performed in the patient room and the interactions with the physical environment were recorded during the observation. 13 RNs providing care to ten patients were observed in seven hours per day, five consecutive days. A total of 35 hours observation was conducted in three identical spatial layout triple-patient rooms from Nov 11, 2018, to Nov 15, 2018. Daily observations were conducted after the morning rounds and before RNs' night shifts (between 10 am and 7 pm).

Participants were observed while performing their daily job routine. The data was collected in observations sessions when RNs would begin direct patient care in the room. Each observation session was defined by the RNs' movements devoted to patient care related activities, starting when the RN left the seat/workstation or entered the patient room to conduct "unit-related functions" and "nursing practices" activities (Table 2-1), and ending when the RN completed the care and returned to the designated nurse station and WOW seat or left the room. Several RN's activities were excluded from observation, such as, when the RN assisted other medical staff or clinicians, when the RN cleaned the patient room to prepare for new patients, and when the RN engaged in personal activities in the patient room (i.e., answering personal phone calls, chatting with co-workers during spare time, and organizing personal belonging).

Data was recorded in an observation sheet (see Appendix B) using a pen-and-paper to identify the current workflow, care delivery activities, and high-contact surfaces of the patient room during each observation. A pilot study was conducted in the same PICU a month before the formal data collection in a triple-patient room for six hours to observe nurses' care delivery process. The results of the pilot study helped the researcher to edit and modify the content and structure of the observation sheet. The observation sheet includes behavior mapping with the general information (i.e., RN number, patient number, start and end time, date) (Figure 2-2), clinical performance chart (Figure 2-3), and 3D interior drawings (Figure 2-4).

During the observation, the RN could notify the researcher anytime to pause the observation for the benefit and comfort of the participant or patients, for example, the observation study was halted if recommended by the RNs (i.e., when bathing the patient) to ensure safety comfort and privacy of patients and their families.

Three tools were included to conduct workflow mapping via observation to assess safety and efficiency during patient care inside the patient room. These three tools tracked the spatial movement, clinical activity and contact transmission and are as follows: a two-dimensional spatial movement mapping tool (2.4.1.1); clinical care activity mapping chart (2.4.1.2); and a contact transmission mapping tool (three dimensional) (2.4.1.3). The following describes each tool:

2.4.1.1 Behavior Mapping

The general information was recorded at the beginning of each observation to code RNs and patients, and the start and end time of observation period of the care delivery.

The tool "behavior mapping" was used to identify the pattern of movement in the space. Behavior mapping was used in the current study to record the RN's current workflow in the patient room while delivering care to patients. The behavior mapping contains an image of a floor plan of a typical triple-patient room in the PICU (Figure 2-2). During the observation, numbers were given to RN conducted tasks based on the sequence. If the RN moved to another location to perform tasks, lines were drawn on the floor plan to show the walking path. The detailed layout of the patient room and equipment on the observation worksheet made it possible to not only document what the RN's care delivery activities but also the location and sequence of the care delivery tasks.

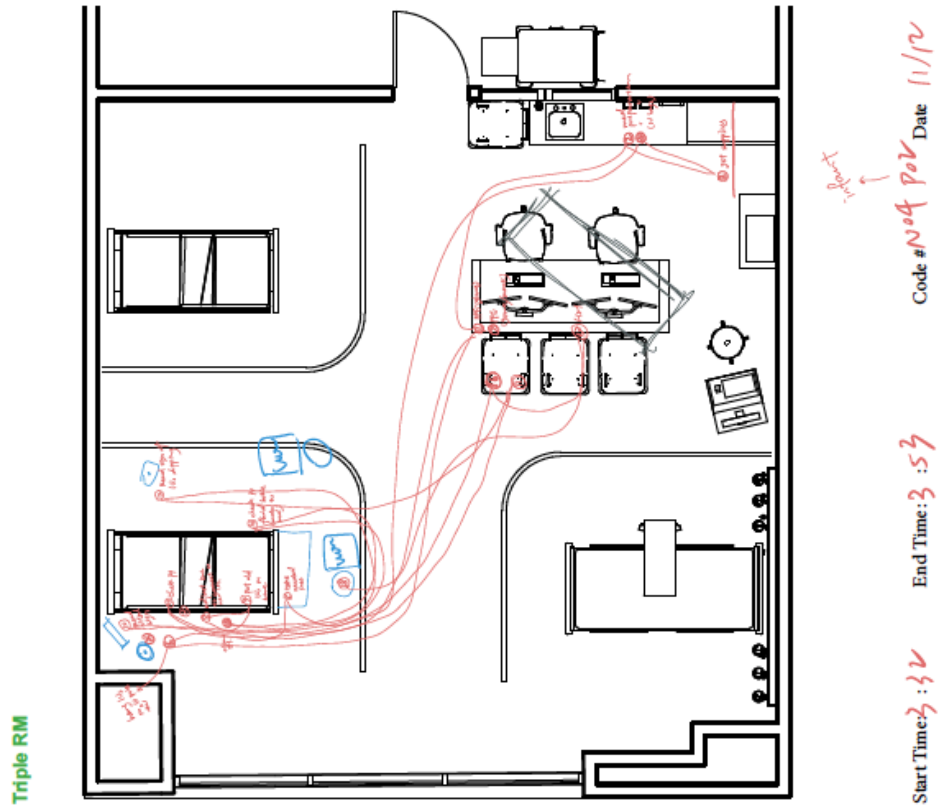


Figure 2-2 Observation Worksheet: Behavior Mapping and General Information

2.4.1.2 Clinical Performance Chart

The clinical performance chart was developed from the literature review, pilot study, and experts consulting to identify RNs' tasks accurately (Table 2-1). After assigning a sequence number to a task, the number was transferred to the clinical performance chart to categorize the task (Figure 2-3). The three main categories developed from Hendrick (2008) and the pilot study are “unit-related functions”, “nursing practice”, and “resource retrieval location” (Table 2-1). Adapted from Hendrick (2008), unit-related functions include “preparing equipment” and “transporting a patient between departments/rooms.” For nursing practice, three sub-categories were developed from Hendrick (2008) including “medication administration,” “documentation,” and “assessment/reading vital signs.” Other sub-categories were developed from expert consultation and the pilot study conducted in the same PICU one month before the formal data collection, including “infection prevention procedure,” “direct clinical patient care,” “indirect patient care,” “communication,” and “sampling blood for lab studies”. Additionally, based on the pilot study, the category of resource retrieval locations was developed to record the locations of resources and supplies. This category includes three sub-categories for locations: around the bedside, in the room, and outside of the room.

Prepare equipment	Unit-related functions	Unit-related functions	
Transport patient			
Hand Hygiene		Infection prevention procedure	Nursing Practice
Get hand soap / paper towel			
Wear PPE			
Continuousl monitoring of vital signs		Direct clinical patient care	
observing the patient to evaluate general condition			
Prepare medication	Medication administration		
Medication administration			
Check the IV electronic readout	Check Iv status		
Untangling IV lines			
Suction patient			
Clean patient			
Comfort/play with patient			
Pick up supplies/medication		Indirect patient care	
Retrieval soiled supplies			
Disposal of sharps, supplies, PPE, diaper & trashes			
Communicate with other care providers		Communication	
Communicate with family members			
Documentation		Documentation	
Sampling blood for lab studies		Sampling blood for lab studies	
Others (Explain)		Others	
Around the bedside		Resource retrieval locations	
In Room (supply closet, nurse workstation)			
Outside of the room (medication room, tube system behind clerk's desk)			

Figure 2-3 Observation Worksheet: Clinical Care Performance Chart

Table 2-1 Categories and Subcategories of Nursing Activities	
Nursing activity category	**Nursing activity sub-category 1**
Unit-related functions [a]	Unit-related functions
Nursing practice	Infection prevention procedures [b]
	Direct clinical patient care [c]
	Indirect patient care [d]
	Communication [e]
	Sampling blood for lab studies
	Documentation
Resource retrieval locations [f]	Around the bedside
	In the room (supply closet, nurse workstation)
	Outside of the room (medication room, tube system behind clerk's desk)

[a] Unit-related functions included preparing equipment and transporting patients between departments/ rooms

[b] Infection prevention procedures included hand hygiene, getting hand soap/ paper towel, wearing personal protective equipment (PPE)

[c] Direct patient care included continuous monitoring of vital signs, observing the patient to evaluate their general condition, checking IVs (including, checking the IV electronic readout, untangling IV lines), administrating medication (including, preparing medication and administrating medication), suctioning patient, cleaning patient, and comforting/playing with patients

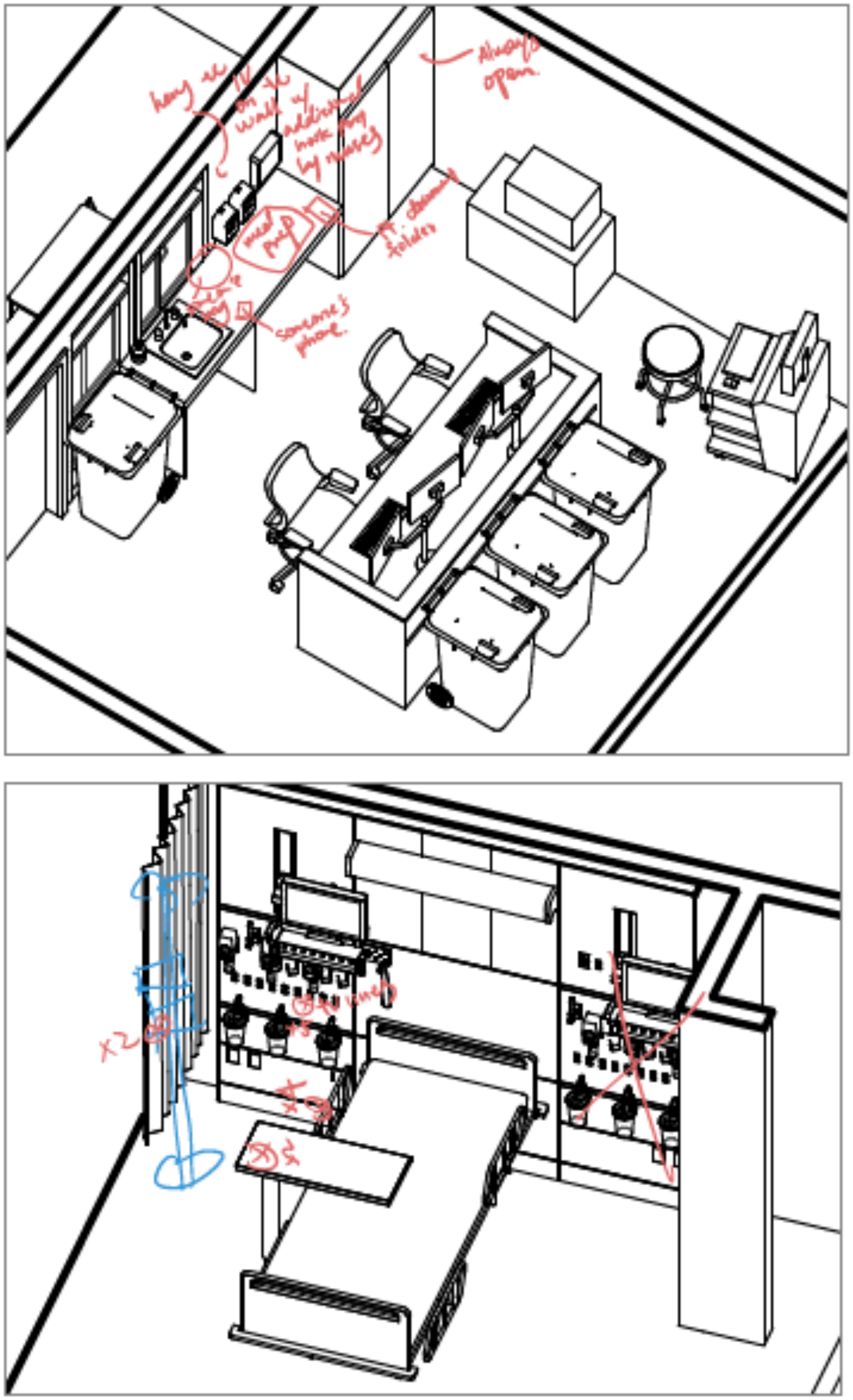
[d] Indirect patient care included picking up supplies/medication, retrieving soiled supplies and disposing of sharps, supplies, PPE, diaper and trashes).

[e] Communication included communicating with other care providers and with family members

[f] Resource retrieval locations referred to the locations of resources/supplies the nurses needed to retrieve during observed care delivery process.

2.4.1.3 Three-Dimensional Drawings

To accurately identify the high possibility of contact transmission surfaces in the patient room during RN's care delivery process, we developed two 3D interior axonometric drawings. The drawings were used to mark when RNs made contact with surfaces and objects during care delivery (Figure 2-4). The 3D axonometric drawings of the patient room work zones were placed on the back of the researcher's worksheet which displays a 3D template for the preparation work zone and the bedside work zone with furniture and medical equipment. To identify high-contact surfaces, the locations that were contacted by RNs and frequencies of these contacts were noted during the observation and organized into the images after each observation.



Triple RM

Figure 2-4 Observation Worksheet: 3D Drawings

2.4.2 In-Person Interview

The purpose of the interview was to learn about 1) the process of care that takes place in the patient room 2) the interactions the RNs have with the environment in the patient room during care delivery and finally 3) the wishes, desires and expectations of RNs about the physical environment of the PICU patient room. Six of the 13 RNs participated, and with each the interview session lasted 15 mins to 30 mins. These in-person interviews were conducted every day after the observation completed in the same patient room. The interviews were conducted based on RNs time availability during their work hours, such as, while the patients were sleeping, or while the RNs did not have care delivery tasks. With the participant's permission, the interview was audio recorded with an iPhone. Three open-ended questions were asked:

1) What types of work are usually done in the patient room?

2) How do you interact with the room environment and medical supplies/equipment when you deliver care in the patient room?

3) What are your opinions, desires, and expectations about the future PICU patient room work zone?

2.5 Data Analysis

Behavioral observation and interviews were each analyzed, and the findings then synthesized. The findings then were combined with our literature review to develop the design recommendations for this unit toward boosting safety and work efficiency.

2.5.1 Observation

Clinical performance chart and 3D drawings were coded into Excel software. For the clinical performance chart, all the observations are combined into a single excel sheet. For each observation, the excel sheet organized the basic information and listed the work step sequence numbers below each activity in the clinical performance chart.

For 3D drawings, the descriptive of activities and frequencies of contact surfaces were tabulated. Moreover, this chart is placed next to the clinical performance chart in the excel sheet in order to associate the contact frequencies with RNs' activities.

For behavior mappings, the researcher identified the top six functional locations in the PICU patient room serving nursing practice and direct patient care: (1) Patient bedside (left), (2) patient bedside (right), (3) disposal area, (4) nurse station, (5) medication and supplies preparation, and (6) outside of the patient room. The traffic flow analysis method was used in the current study and referred to RNs travel frequency. Moreover, this analysis method helped to show the inter-relationship between the identified six areas by counting the number of RNs' movements between areas, as shown in Figure 2-5. Therefore, based on the traffic flow analysis, the higher traffic flow, the stronger adjacency of the areas should be.

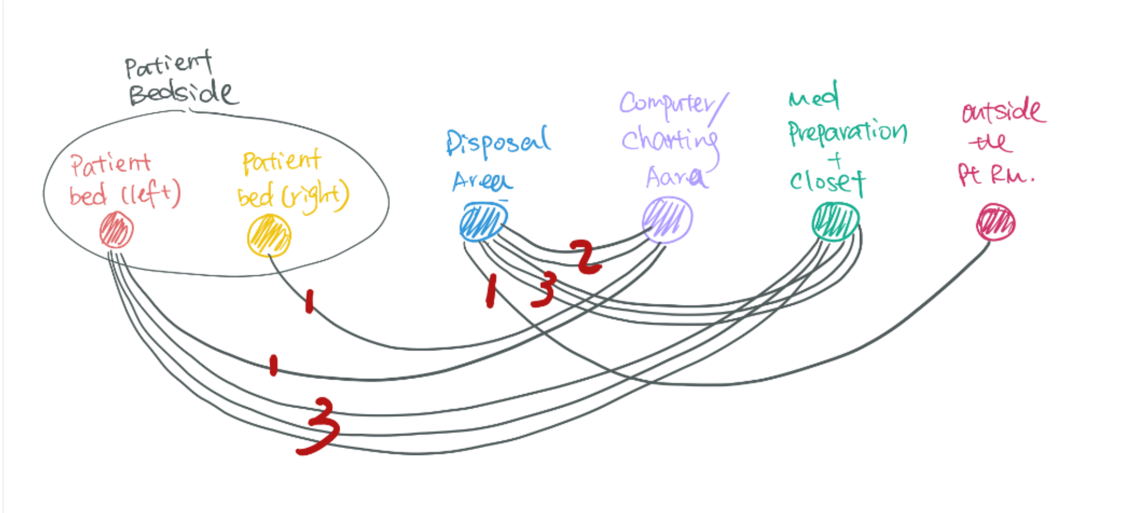


Figure 2-5 Example of Traffic Flow Analysis of One Behavior Mapping

2.5.2 In-Person Interview

The interview content was transcribed digitally into a word document after, and the recording files were deleted permanently for maintaining anonymity. Any identifier was eliminated from the transcription. We only included data that was related to the work zone in the patient room physical environment (Appendix F). Thus, information shared which was related to family zone, bathrooms, televisions for families and patients use, and the PICU operational policies were not included in the analysis for this study.

The transcribed interview content was thematically analyzed and clustered based on their themes, for example, nurse station, sink location, etc. Besides, the interviews are also grouped based on the interview questions about RNs' thoughts about the current work environment (positive and negative), and future expectations.

CHAPTER 3

RESULTS

3.1 Profile of Participating Nurses

A total of 48 observations were collected during 35 hours in three triple-bed patient rooms from 13 female registered nurses and ten patients in five consecutive weekdays between 10am to 7pm (Table 3-1). A total of 539 clinical tasks conducted by RNs were documented. None of the observations were eliminated due to participant drop out.

Table 3-1 Demographic Statistics

Characteristics	
Participants (RN), *n*	
Women	13
Men	0
Observed Patients, *n*	10
Studied patient rooms, *n*	3

*No access to patient age in the current study

3.2 Work Efficiency: Behavior Mapping Traffic Flow Analysis

Table 3-2 shows the RNs movement frequencies between six identified spaces during the 35 hours observation. Higher walking with the order of frequency happened between two sides of the patient bed (19.7%, 51 times), the bedside (left and right) and the disposal area (23.9%, 68 times), and the disposal area and the nurse station (13.5%, 35 times) compared to other functional spaces in the patient room (<10%). The traffic flow between the areas inside the patient room and outside the patient room (in the unit) is low, in other words, RNs rarely walk outside of the room during care delivery to the patients. In addition, the traffic flow analysis indicated that a higher traffic flow from the patient bedsides to the disposal area compared to the medication preparation and closet and the nurse station.

Table 3-2 Behavioral Mapping Traffic Flow Analysis

from - to zones within shared patient room frequencies, *n* (%)	Bedside left zone	Bedside right zone	Disposal area	Nurse station	Med preparation + closet	outside
Bedside left zone		51(19.7%)	35(13.5%)	21(8.1%)	16(6.2%)	1(0.4%)
Bedside right zone			32(12.4%)	20(7.7%)	9(3.5%)	2(0.8%)
Disposal area				35(13.5%)	9(3.5%)	9(3.5%)
Nurse station					14(5.4%)	4(1.5%)
Med preparation + closet						1(0.4%)

Based on the walking frequencies of the traffic flow analysis (Table 3-2), the adjacency diagram was generated to illustrate the physical proximities of these six areas (Figure 3-1). Each bubble in the diagram presents one physical space in the patient room. There are three different line thickness that indicate three levels of adjacency. The thicker the line is, the higher adjacency is required. Because of the high walking frequencies between two sides of the bed and between the bedside area and the disposal area, "immediate adjacency" is required. The "general adjacency" and "near" levels of adjacency indicate that the current spatial layout could support RNs work and do not overly add extra walking and inefficiency but could be further improved.

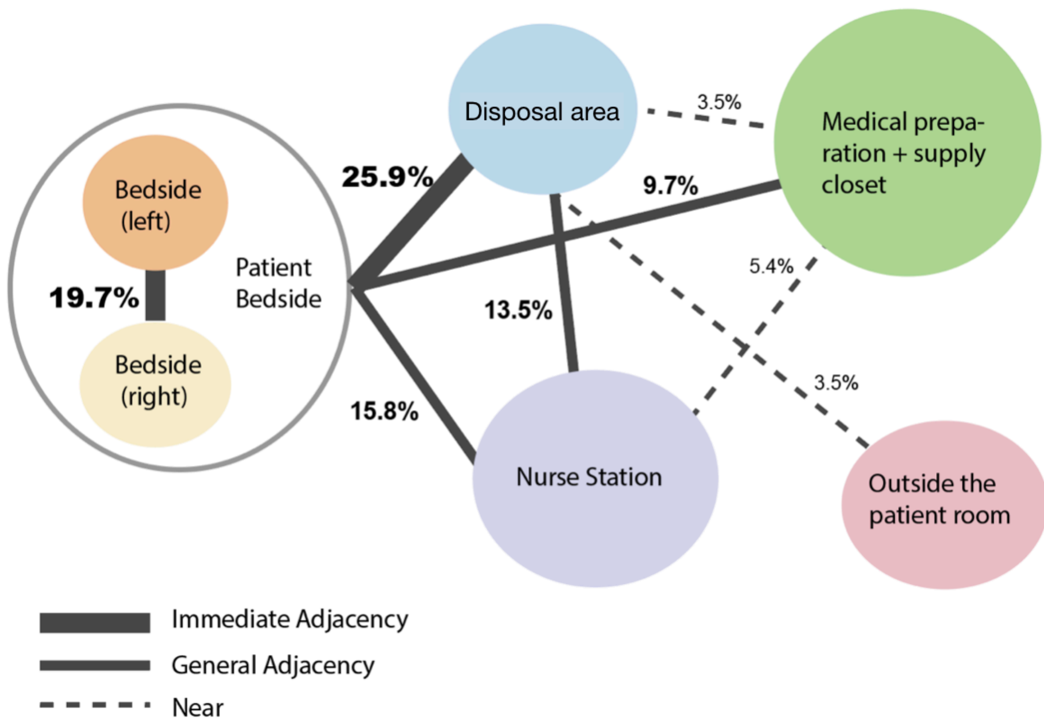


Figure 3-1 Traffic Flow Adjacency Diagram

3.3 Work Efficiency: Clinical Performance Chart

RNs' care delivery activities performed in the patient room are identified in the clinical performance chart. All the clinical performance chart of the 48 observations were combined and organized into excel documentation.

A total of 539 tasks performed by RNs were observed. Figure 3-2 below provides the breakdown based on the developed clinical performance chart of nursing activities in the patient room. Between the observed weekdays between 10am and 7pm, direct clinical patient care was the major task RNs performed in the patient room (164 times or 30% of the total observed clinical care performed). Similar, indirect patient care was conducted 165 times or 31% of the total 35 hours observation. Infection prevention procedure accounted for the third largest proportion of RNs steps taking during the care delivery in the patient room; in fact, this category by itself accounts for 16% of all reported numbers of steps (86 times), more than family and clinical communication, documentation, sampling blood for lab studies, and unit-related functions, which are under 10% of all reported numbers of steps taken.

The main category of direct clinical patient care (3.3.1), indirect patient care (3.3.2) and infection prevention procedure (3.3.3) were further analyzed to understand the specific activities conducted times.

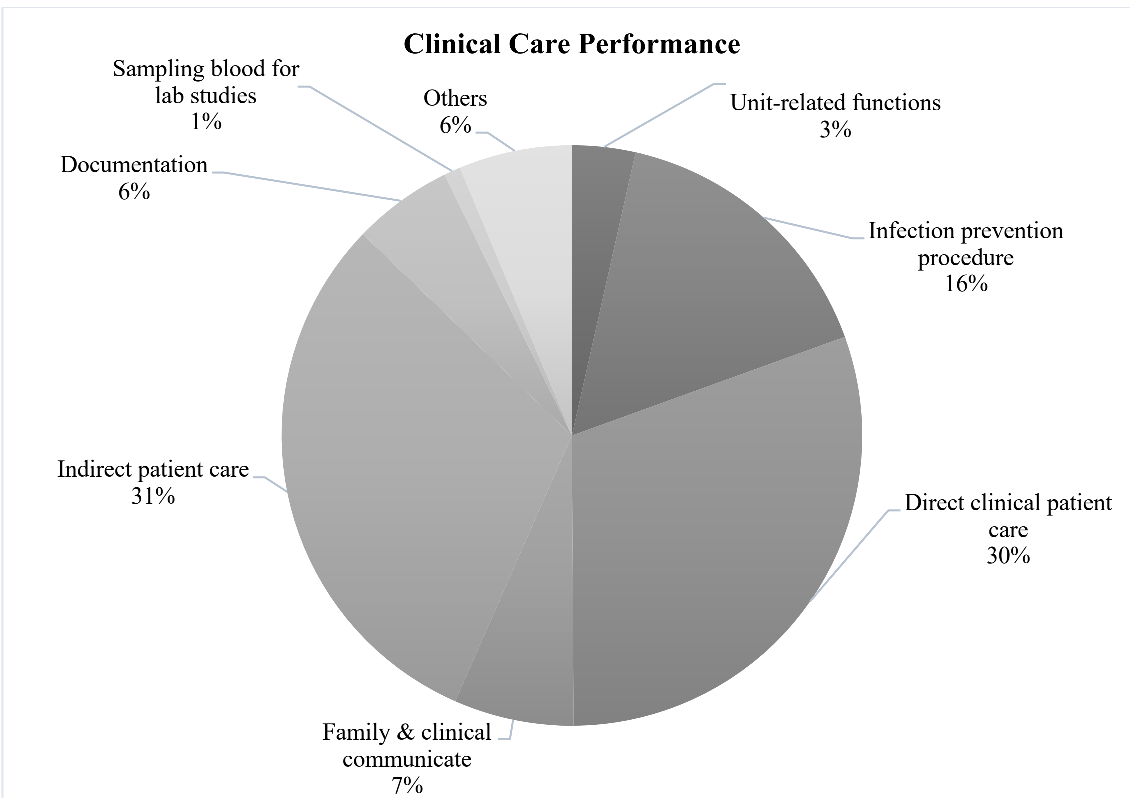


Figure 3-2 Clinical Care Performance Breakdown Pie Chart

3.3.1 Direct Clinical Patient Care

A total of 164 direct patient clinical care tasks were recorded during the observed 48 care delivery processes for 10 patients. Figure 3-3 presents the breakdown of the direct patient care subcategories. RNs checked IV status 64 times (39% of direct patient care steps), including activities of "checking the IV electronic readout" (30 times) and "untangling IV lines" (34 times). Additionally, 22 times or 17% of direct patient care steps were spent on "observing the patient to evaluate their general condition and vital signs." Continuous monitoring of vital signs and medication administration take 13% and 10% of direct patient care steps respectively.

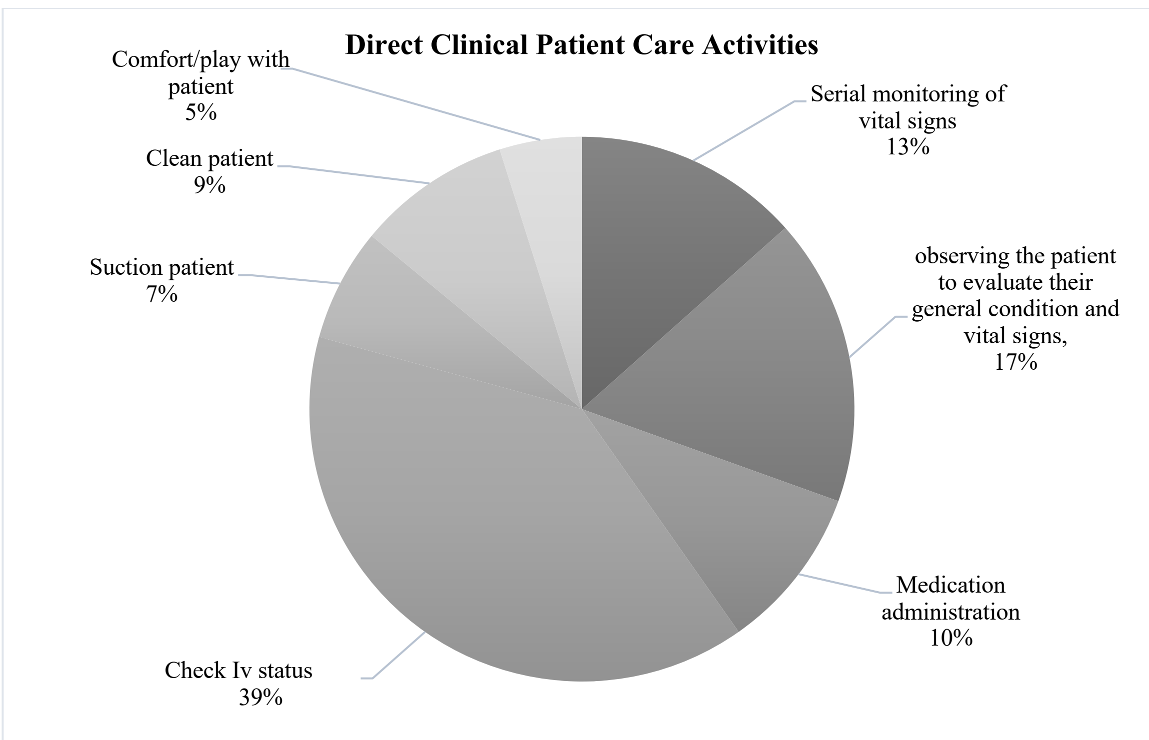


Figure 3-3 Direct Clinical Patient Care Breakdown Pie Chart

3.3.2 Indirect Patient Care

A total of 165 indirect patient care tasks were observed during the 35 hours observation. Figure 3-4 shows the breakdown of the indirect patient care tasks subcategories. The majority steps of indirect patient care spent on wastes disposal, including sharps, supplies, PPE, diaper, and trashes, which accounted for 49% (77 times) of the indirect patient care steps. RNs devoted similar number of steps on "picking up supplies/medication" (45 times) and "retrieval trashes" (43 times) during the observation.

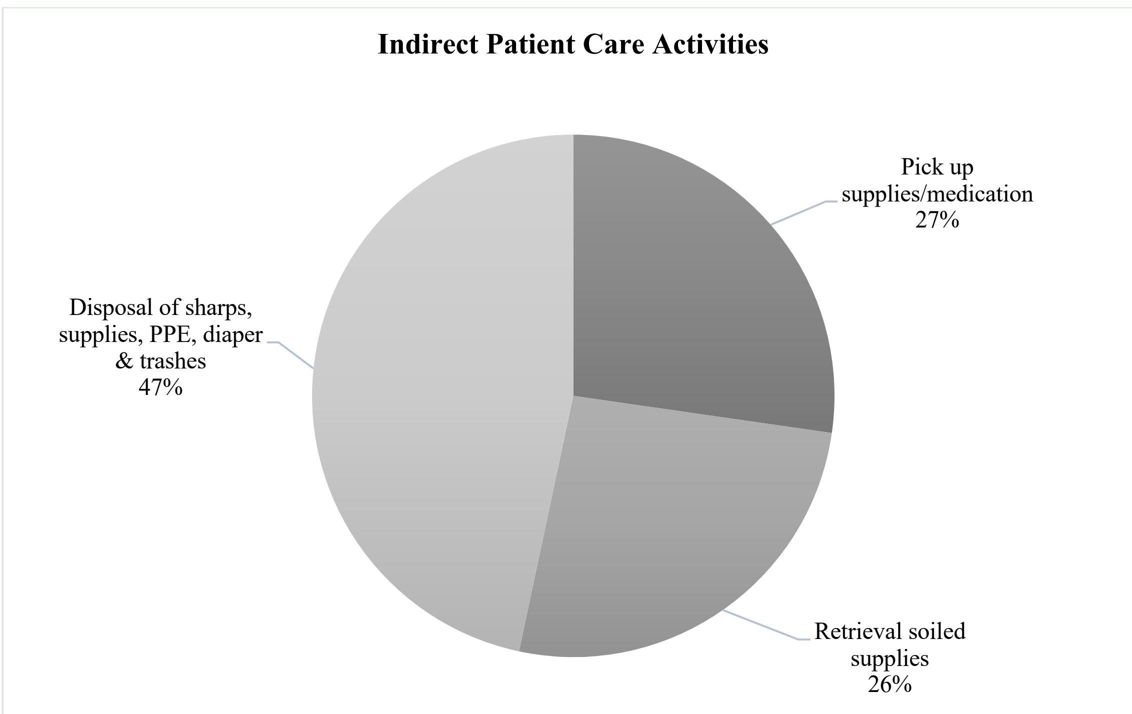


Figure 3-4 Indirect Patient Care Breakdown Pie Chart

3.3.3 Infection Prevention Procedure

A total of 85 infection prevention procedure tasks of 539 total observed RNs' activities were recorded. The majority steps spent on "wearing PPE," which is 62% of the total steps on infection prevention procedure (53 times). Hand hygiene took 36% of infection prevention procedure steps or 31 times; however, "getting hand soap / paper towel" only took 2% of RNs steps while conducting infection prevention procedure tasks.

3.4 Contact Infection Transmission: Three-Dimensional Drawings

Figure 3-5 provides findings of high probability of contact transmission surfaces during care delivery process in the studied triple-patient rooms. A total of 156 contacts were recorded during the 35 hours observation. The most frequently contacted surfaces are as follows: 1) Patient bed rails, 63 times 2) IV pumps and poles, 26 times, 3) tubing and medical equipment around the bedside, 23 times, and 4) vital sign monitor screens, 20 times.

In addition to the top four high contact surfaces, the patient bedside table (11 times) and cubical curtains (8 times) have relatively high contact frequencies as well compared to other surfaces in the patient room during the 35 hours observation.

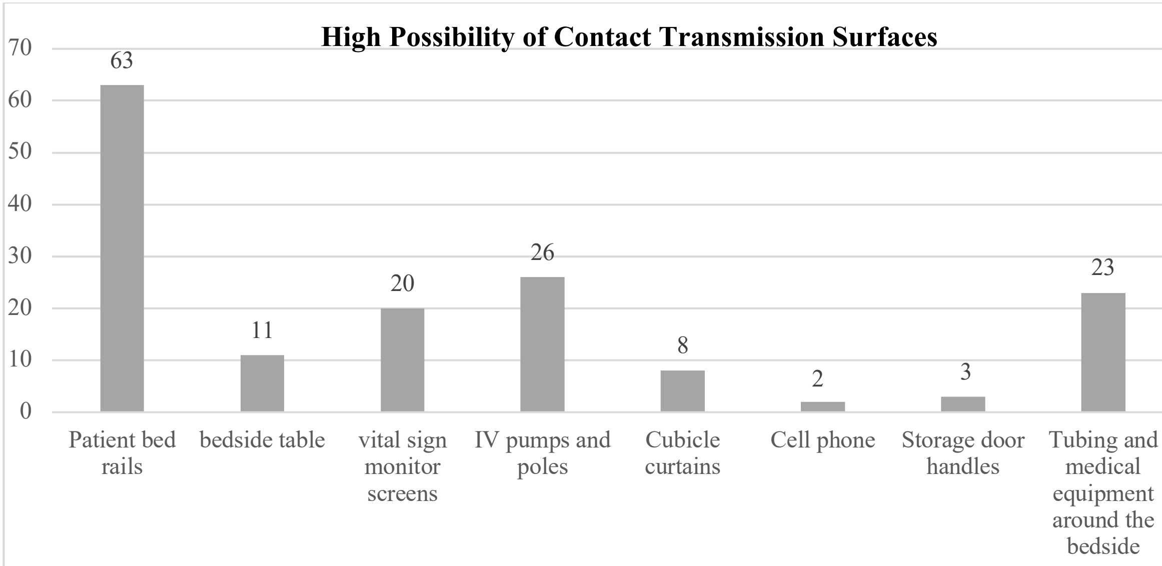


Figure 3-5 High Possibility of Contact Transmission Surfaces in the Patient Room

The nursing care activities that associated with high contact surfaces of patient bed rails (3.4.1), tubing & medical equipment around the bedside (3.4.2), and IV pumps and poles (3.4.3) were further analyzed according to the data from the clinical performance chart.

3.4.1 Patient Bed Rails

Figure 3-6 provides the breakdown based on the individual care delivery activities performed by RNs related to contact patient bed rails. Conducting direct patient care resulted in contacting the patient bed rails 46 times of a total of 63 times during the 35 hours observation. To be more specific, checking IV status (13 times), cleaning patient (10 times) and suctioning patients (10 times) are the three main activities under direct patient care that led RNs to contact the patient bed rails.

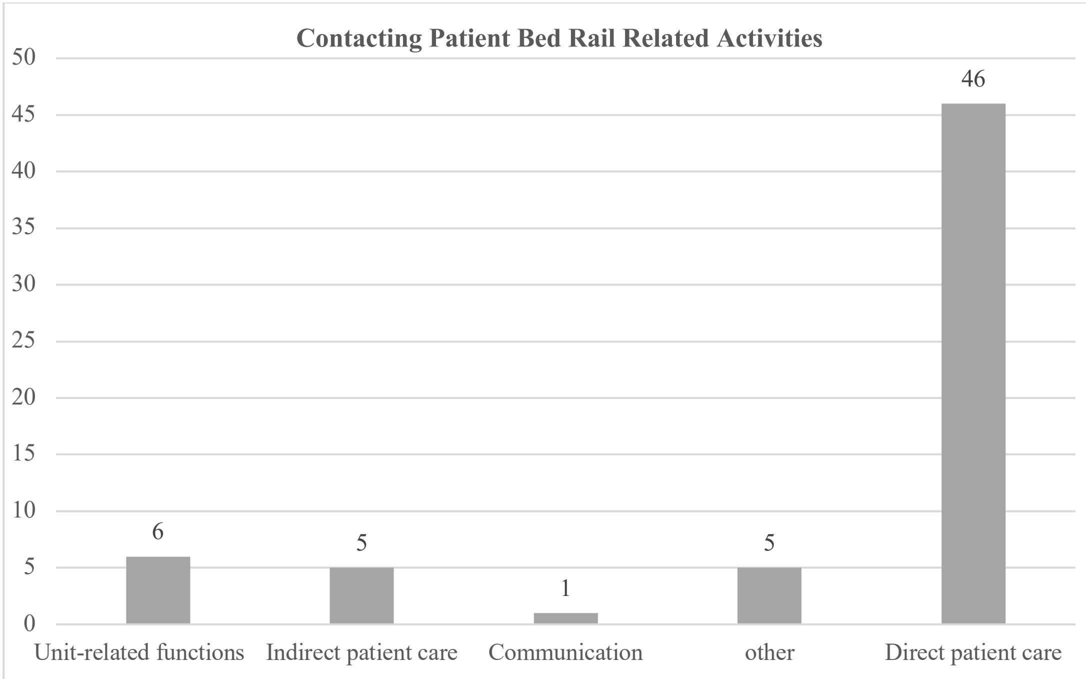


Figure 3-6 RNs Care Activities Associated with Contacting the Patient Bed Rails

3.4.2 IV Pumps & Poles

The activity of checking IV status conducted by RNs led to contact with the IV pumps and poles 15 times of a total of 26 times during the observed care delivery process. To be more specific, checking the IV electronic readout (10 times) and untangling IV (5 times) are two activities under direct patient care resulted in contacting the IV pumps and poles.

3.4.3 Tubing & Medical Equipment Around the Bedside

Figure 3-7 illustrates RNs care activities associated to high contacting frequencies on tubing and medical equipment around the bedside (23 times of the total of 156 recorded contacts). Direct patient care accounts for the major activity that led to contact wires and equipment (8 times). To be more specific, under the direct patient care activity, "untangling IV lines" (6 times) and "continuous monitoring of vital signs" (2 times) are the two main activities that associated with contacting the tubing and medical equipment around the bedside during the 35 hours observed sessions. In addition, unit-related function resulted in 7 times of a total of 23 times contacting the wires and equipment around the bedside during the observed care delivery process.

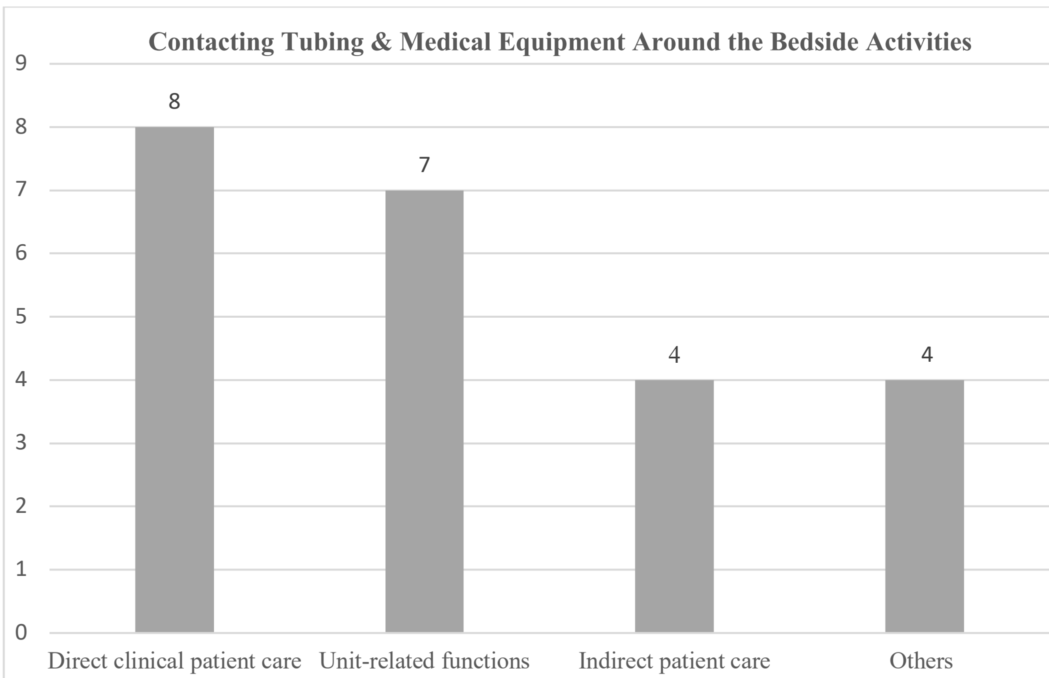


Figure 3-7 RNs Care Activities Associated with Contacting Tubing and Equipment Around the Bedside

3.5 In-Person Interview

The analysis of the RNs' interviews resulted in six categories of data. These categories are design features related to the following: nurse station, supply retrieval/ disposal, medication preparation, sink, bedside work zone, and vital sign monitor.

Under each category, RNs' comments of both the current (positive/negative) and the ideal condition are summarized (Appendix F). Moreover, the interviews provided supplementary and supportive information to the findings from observation studies.

Supply retrieval / disposal. RNs' supply retrieval process is positively supported by the fact that the supply closet is in the patient room and not too far away from the patient bedside. This is also confirmed by the behavioral mapping data indicating a considerable heavy traffic flow between the preparation area and the bedside, which suggests that by moving this supply resource to outside of the room could introduce inefficiency. One RN described the supply retrieval process during the interview as, *"...you have to think ahead, so you have to know, ok, I'm about to do this activity, I'm about to draw blood, I need all the tubes, gauges... so, you need to think ahead to bring to the bedside, which is something you learn from time, but it is not something comes naturally"* (RN, interview, Nov. 15, 2018), which suggested the presence of non-value-added steps that should be eliminated. Another RN described the following regarding the disposing of waste could be further enhanced to save time and steps: "*…if you are changing a diaper and using other material that is the garbage, you would pile them on the bed, and then bring it together to the garbage, you will not go one by one. It would be probably helpful if there is a garbage can closer to the bedside"* (RN, interview, Nov. 13, 2018). This interview finding is also supported by the behavioral mapping data indicating high traffic flows between the bedside and the disposal areas, which suggests the current location of disposal area added inefficiency.

Bedside work zone. Interviews reflected the lack of space around the bedside due to the nature of activities performed in these zones, as well as the frequent walking between the two sides of patient bedsides to conduct direct patient care activities. RNs described the needs for more space and work surfaces around the bedside, as *"I put myself in danger trying to plug things in and take them out like where I could trip where I could get caught in my patients shooting and then harm them,…we do end up putting on the bedside table*…[and]*…sometimes, it is a little bit narrow from one side of the bed to the other, the overlap between the family couch and the work zone"* (RN, interview, Nov. 14, 2018). The traffic flow and safety issues found in the interview are supported by the behavioral mapping data indicating a high traffic flow between the two sides of patient bed. This interview results also provided supportive reasons for the identified high contact surfaces results (e.g., patient bed rails, the patient bedside table and the tubing and medical equipment around the patient bedside).

Vital sign monitoring. Interviews' content of the vital sign monitor revealed that the current monitoring system and arrangement in the unit could hinder RNs' work efficiency and lead to higher contact frequencies with the monitor screens. RNs described that *"a lot of times the alarm beeps, so every time you either have to walk over there, or we have these remotes, these remotes always do not work, a lot of them are broken... so theoretical can turn off the alarm of the monitort... but you have to look up and see the vital signs... it is pretty loud beeps,"* but *"when curtain closed, you cannot see the patients' monitor"* (RN, interview, Nov. 12, 2018). The interview provided supportive reasons for the 3D drawings' results of the high contact frequencies with the vital sign monitor screens.

On the strategic placement and design of the 'sinks', 'computer/charting nurse station' and 'medication preparation', the comments highlighted the need for additional work surfaces for computer charting, lab works and medication preparation, clearance in front of the sink, and designated areas for lab works and PPE storage for infection control and prevention purpose. RNs believed these improvements were related to their day-to-day safety and efficiency. This information was not particularly noted in the behavioral mapping and clinical performance chart.

RN's feedback of ideal future work environment in the patient room was also organized into the six categories and discussed further in the design guidelines in the discussion chapter.

CHAPTER 4

DISCUSSION

This study investigated the features of the physical environment that may support efficient and safe care delivery in multi-bed PICU patient rooms. Combining the findings of the observational studies and in-person interviews, a number of opportunities to optimize the physical work environment in the multi-bed PICU rooms were identified.

The following sections summarize the findings on RN's work efficiency and contact infection. They also present the effect of the built environment on work efficiency in terms of access to supplies and seamless and unhindered completion of the clinical processes (4.1), and on safety in terms of contact transmission prevention (4.2). Future design recommendations are also provided for work efficiency and safety.

4.1 Work Efficiency

The study had several important findings related to RNs' work efficiency. First, the summary of our finding indicated that RNs' work efficiency could be improved around the bedside area. The analysis of the traffic flow showed a high frequency of movement between two sides of the patient bed highlighting the importance of the space around the bedside for RNs' care delivery process. Previous studies also indicated that lack of space around the bedside is a significant issue, because it could hinder RNs' work process, reduce work efficiency and increase physical efforts (Thompson et al., 2012; Lavender, Sommerich, Patterson, Sanders, Evans, Park, Umar & Li, 2015). Most RNs' steps around the bedside spent on "checking IV status" (64 times of a total of 539 times), "continuous monitoring of vital signs" (22 times of a total of 539 times), and "observing the patient to evaluate their general conditions" (28 times of a total of 539 times), which are subcategories of "direct clinical patient care," are considered as value-added activities. However, RNs reported that they put extra steps and efforts on walking around the bed to turn off the alarm on the monitors and check patients' status. Thus, by reducing these "over-processing" steps – which are the processes or procedures in the system that do not add value to the end users (Liker, 2004) - could improve RNs' work efficiency around the bedside. This could be achieved by providing more space around the bed. Providing circulation space behind the head of the bed could also shorten the walking distances between the bedside. In addition, a ceiling mounted beam would sustain resources (for example power, oxygen, monitor etc.) needed at the bedside, provide room for circulation, and reduce clutter from equipment, lines and tubes (Thompson et al., 2012; Kesecioglu, Schneider, van der Kooi & Bion, 2012). Furthermore, a study indicated that by providing the remote control of the monitors, RNs could monitor patient's condition from the nurse station or even outside the patient room without consistently walking to the bedside (Kesecioglu et al., 2012). The detailed design recommendations are presented later (4.1.1).

Second, the findings indicated that RNs' work efficiency could be improved between the bedside and the disposal area. The analysis of the traffic flow presented a high frequency of movement between the patient bedside and the disposal area, highlighting the importance of the space adjacency between these two areas. The majority of RNs' steps between these two areas were spent on "disposing of sharps, supplies, PPE, diapers, and trash" (77 times of a total of 539 times), which is under "indirect patient care" activity. This is not considered as a direct value-added activity but may support the care task. A previous study supported the finding and concluded that 34.3% of 10000 RNs, who work in adult hospitals in Pennsylvania, reported that they spent a significant portion of their time in performing house-keeping duties which includes disposing of trashes (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002). RNs in the current study also reported that they devoted extra steps to dispose of all the trashes after the care delivery process. Thus, opportunities may exist to streamline care process and reduce the non-value-added steps to improve work efficiency. This could be achieved by providing portable sharp containers and trash receptacles to places that are visible, within reach range, and free from obstruction during the care delivery process (Thompson et al., 2012).

Third, the results indicated that RNs' work efficiency could be further improved from the bedside to the nurse station and the medication preparation area. The adjacency diagram (Figure 3-1) showed that improved adjacency would be beneficial between the bedside and the preparation area, and between the bedside and the nurse station. "Picking up supplies/medication" (45 times of a total of 539 times) and "wearing PPE" (53 times of a total of 539 times) are RNs' activities that caused a majority of walking between these areas. Previous studies supported the finding, because they indicated that nurses spend a lot of walking to locate and gather supplies and equipment and resulted in wasting time, delaying patient care, increasing RNs' frustration and decreasing quality of care (de Leval et al. 2000; Beaudoin and Edgar 2003; Cleary 2003; Tucker

2004; Tucker &Spear, 2006; Rathert, Fleig-Palmer, and Palmer 2006). RNs also reported during the interview that to reduce extra steps to go back to the supply unit to recollect supplies, they tend to collect a host of supplies they may need before going to the bedside. Thus, saving the steps that do not add direct values to nursing activities may help improve work efficiency. This could be achieved by providing decentralized supply locations at the patient beds, which was found could reduce RNs' walking distance (Shepley, 2002; Shepley & Davies, 2007). The ceiling mounted beam suggested before could also provide additional storage for necessary supplies at the bedside.

4.1.1 Future Opportunities to Improve Work Efficiency

Based on the study findings, we concluded the built environment of the PICU multi-bed patient room could be designed to support RN's work efficiency by reducing excessive steps that RNs take. Prior studies showed that excessive walking and unnecessary journeys in the healthcare environment could not only decrease staff satisfaction level, but also contribute to non-productive and inefficient care delivery (Pati, Harvey & Thurston, 2012; Copeland & Chambers, 2017). Possible adjustments to the patient room design to improve workflow and reduce excessive steps are as follows:

1. Providing sufficient walking space around the patient bed for RNs to gain access to all the equipment to carry out procedures could reduce accidents, mistakes, and delays occurring (NHS Estates, 2008). Adequate space for circulation around the bed and circulation at the head of the bed as shown in Figure 4-1 and Figure 4-2 is recommended. This is supported by the front line staff interviews,

as explained by an RN: *"...proving walking space behind the bed, where even machines can be pushed and angled there, and you have access to the patients from both sides, but you can get to the machines on both sides but out of your way."*

2. Providing a ceiling mounted flexible beam that is allowed to be rotated and easily moved around the patient bed may be a solution to reduce unnecessary walking between bedsides, Figure 4-2 (Thompson et al., 2012).

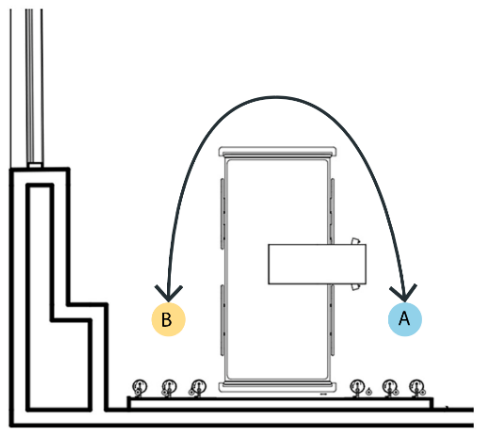


Figure 4-1 Current Workflow around the Bedside

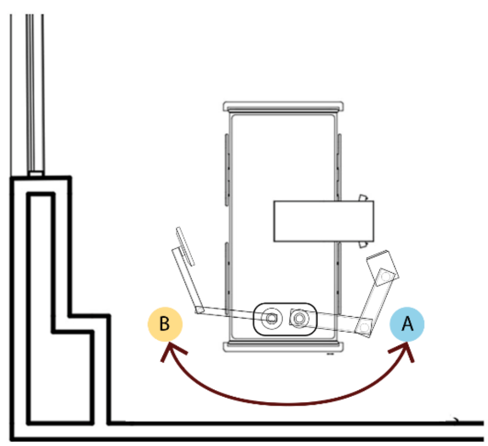


Figure 4-2 Proposed Workflow around the Beside with Ceiling Mounted Beam Arms

3. Providing decentralized supplies that are near the point of care and easily accessible. As supported by past research, decentralized supplies could improve work efficiency and reduce RNs' walking distance (Hendrich, 2003; Shepley, 2002; Shepley & Davies, 2007). For example, placing sharp containers, garbage receptacles, and contaminated supply disposal units such that are visible and within the reach range of the patient bed.
4. Providing a designated staff mobile work cart/ surface stored within the entry as part of medication preparation space to include PPE, necessary supplies, IV pole, and receptacles is recommended to reduce walking distance between the preparation work zone and the bedside (Figure 4-3). This is supported by past evidence and the RNs' interviews that lack of work surfaces around the bedside lead to high work challenge (Lavender et al., 2015; RNs, interview, Nov. 15, 2018).

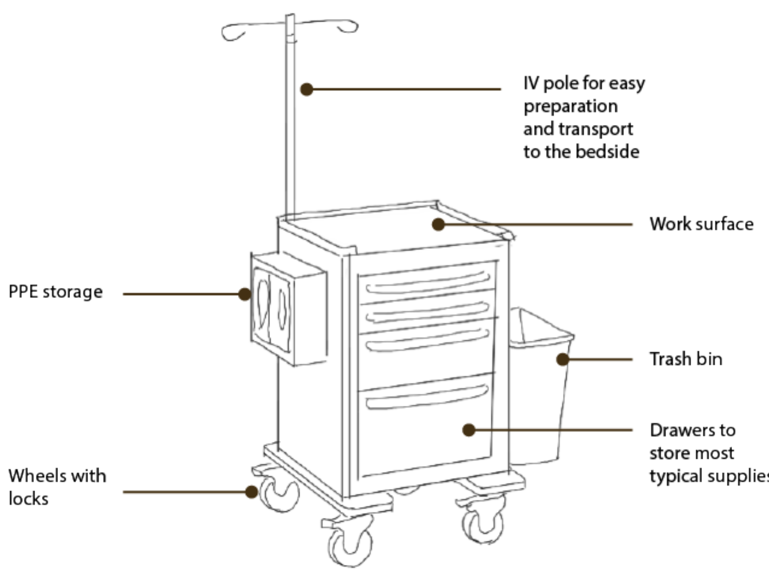


Figure 4-3 Example of Multi-Functional Mobile Work Surface/Cart

5. Facilitating line of sight to vital monitor screens for the patients both at the station and around the patient care areas are recommended. Providing a central vital sign monitor screen (Figure 4-4) with remote controllers or portable vital sign monitor iPad devices for RNs may be a possible solution. A vital sign monitor screen at the nurse station that allows RNs to monitor three patients at the same time could reduce extra walking to check and turn off alarms on monitors. A previous study also found that the alarm is one sensory distracter that could hinder HCWs' work efficiency (Spreckelmeyer, 2004).

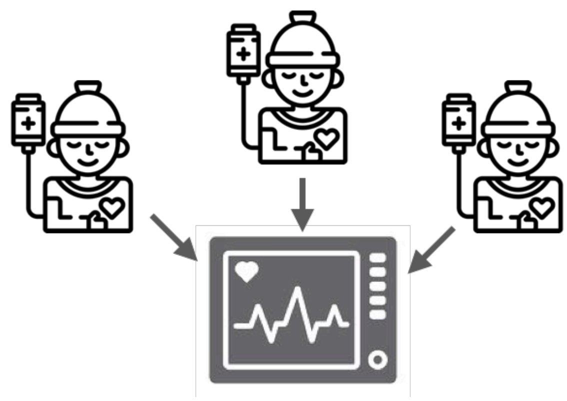


Figure 4-4 Central Monitor Screen with All Three Patients Vital Sign Information

6. Providing ergonomically designed work stations, furniture, and appropriate lighting levels for charting and medication preparation area is another recommendation. Previous studies found that back support task chairs, adequate and bright work surface with illumination levels between 1500 to 2000 lux, and sufficient space for feet movement close to the counter could facilitate RNs'

work efficiency (Chaudhury, Mahmood & Valente, 2009; Ulrich & Barach, 2006).

4.2 Safety

The findings presented four surfaces as the highest possibility of contact transmission surfaces: patient bed rails, IV pumps and poles, tubing and medical equipment around the bedside, and vital sign monitor screens. A previous study also rated “bed rail,” “IV pump,” “monitor,” “IV tubing and monitor cables” as the top high-contact surfaces of 28 common surfaces in intensive care units (Huslage, Rutala, Sickbert-Bennett, & Weber, 2010). Moreover, the over-bed table and the cubicle curtain are found as the fifth and sixth high possibility of contact transmission surfaces. These surfaces are prone to be contacted not only RNs, but also HCWs, patients, families, and visitors leading to a high potential for cross-contamination (Dancer et al., 2009; Trillis, Eckstein, Budavich, Pultz, & Donskey, 2008).

4.2.1 Workflow and Contact Transmission

The findings indicated that RNs’ workflow could influence their contact frequencies with high possibility of contact transmission surfaces. Based on the literature review, the facility layout, equipment placement, and design could affect RNs movement flow in the space which could directly impact the infection prevention compliance (Anderson, Gosbee, Bessesen, & Williams, 2010; Kumar & Storch, 2004). Hence, by optimizing the movement flow in the patient room, there is a chance to reduce the possibility of contact transmission (Cohen et al., 2014; Son et al., 2011). For example, in the current study, if the number of steps from one bedside to the other is reduced, the frequency of contacting with the patient bed rails by RNs could be reduced as well.

4.2.2 Future Opportunities to Reduce Contact Transmission

Based on the study findings, we concluded the built environment of the multi-bed patient room could be designed to reduce the possibility of contact transmission by optimizing the workflow and design of the amenities. Previous studies have proved that taking this step along with improving cleaning and hand hygiene processes could reduce contact contaminations (Anderson et al., 2010; Cohen et al., 2014). Recommendations could assist to achieve the goal are listed below:

1. Frequent cleaning of the identified high-contact surfaces to help reduce the possibility of transmission is recommended. Another possibility is investing on applying antimicrobial material for these surfaces. Schmidt et al. (2012) found that copper surfaces, compared to standard surfaces in patient rooms, resulted in an 83% reduction in bioburden. The proportion of patients developing HAIs was lower by 42% to 56% among copper-surfaced ICU rooms compared with standard rooms (Salgado et al., 2013). Inorganic metals and polycationic surfaces are also found to be effective in reducing the rate of HAIs (Lansdown, 2006; Stobie, 2010; Klibanov, 2007). Light-activated antimicrobial material could be used for the tubing, wires, and finish coatings to reduce pathogens. For example, photosensitizer-containing coating and medical grade silicone that is incorporated with crystal violet and methylene blue and gold nanoparticles have

strong antimicrobial activity under both white lighting and dark conditions (Wilson, 2003; Noimark, Allan, & Parkin, 2014).

2. Improving the accessibility to sinks or alcohol-rub dispensers to improve RNs' hand hygiene and infection prevention compliance is recommended. This may reduce extra steps and facilitate safety compliance. Multiple studies pinpointed hand hygiene as an essential intervention in improving infection control, especially contact infection (Boyce & Pittet, 2002; Pittet et al., 2006). Bischoff and colleagues (2000) suggested the implementation of multiple interventions, including "bedside alcohol-based hand-rub dispensers." They found that these interventions led to substantial improvements in hand hygiene compliance, and led to significant reductions of bacterial load, the occurrence of HAIs, and cross-contamination.
3. Providing a designated staff mobile work surface around the bedside for RNs to reduce the chance of using the patients' over-bed table, which has a high potential for cross-contamination surface.
4. Providing "from clean to dirty" movement flow in the preparation work zone could optimize RNs' workflow and minimize cross-contamination (Figure 4-5; Figure 4-6). A previous study found that moving from "clean" (protected from pathogens) to contaminated area could support transmission prevention but moving in the other direction would require cleaning or application, such as sink, hand sanitizer, and PPE, to reduce bacteria and pathogens (Hor et al., 2017). Thus, as shown in Figure 4-6, the sink and PPE storage are placed next to the

trash bins to ensure the layout could support transmission prevention for both circulation directions.

5. Providing designated PPE store locations that are adjacent to the entry and each patient bedside may improve infection prevention and reduce steps. Also, this may reduce visual clutter of the unit as currently the PPEs are scattered on the nurse station. A study found that hand hygiene frequency is higher when the users have higher visibility to the hand sanitizing stations (Neo, 2016). For example, using isolation tower and wall mounted PPE organizer in the patient room saves horizontal spaces on the nurse station and increases the accessibilities as well (Figure 4-7; Figure 4-8).

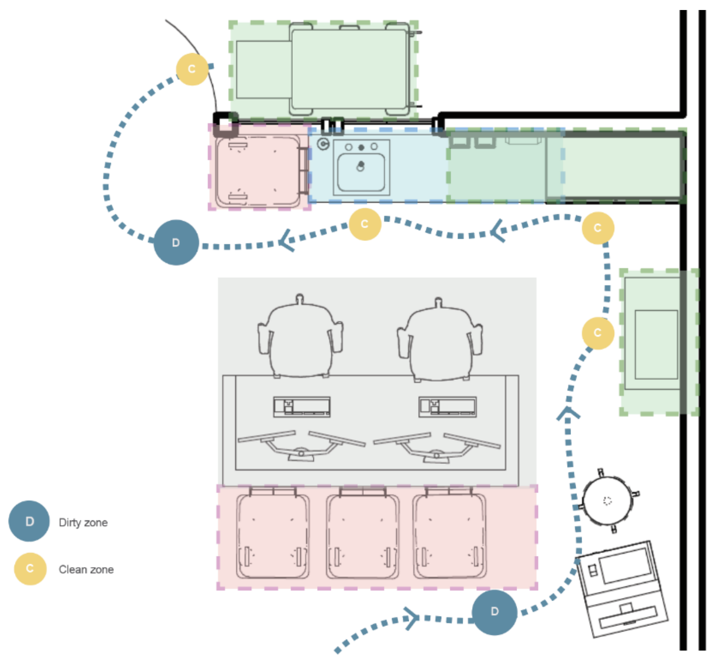


Figure 4-5 Current Workflow in Preparation Zone

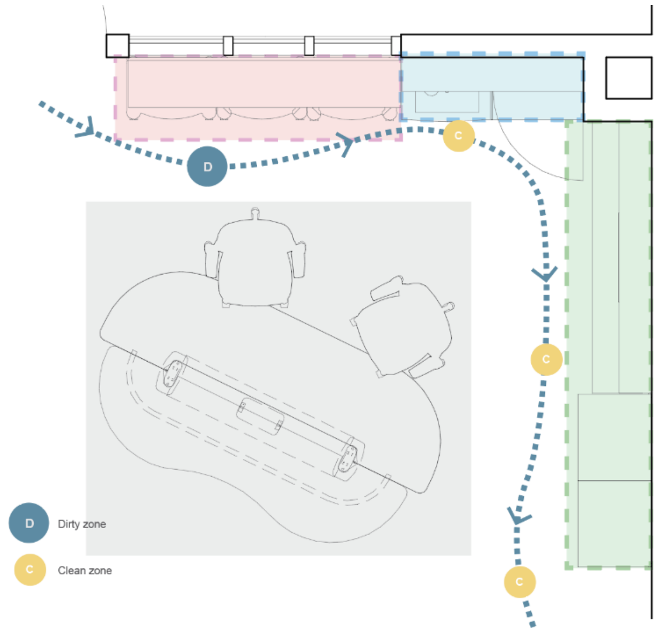


Figure 4-6 Proposed "from Clean to Dirty" Workflow in Preparation Zone

6. Generating a room cleaning checklist in the infection prevention protocol and especially monitoring the top six high-contact surfaces identified by the current study. A previous study found that less than 50% of surfaces are cleaned during a terminal cleaning process in the patient room, though ideally all environmental surfaces should be disinfected at a terminal cleaning after the patient discharge, especially in an ICU environment (Carling et al., 2008).

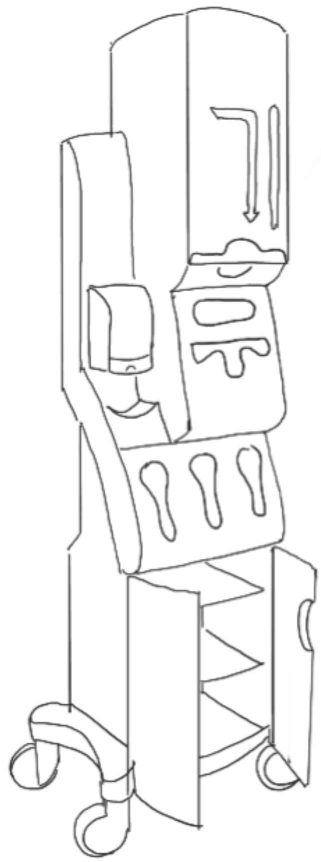


Figure 4-7 Example of Isolation Tower

Figure 4-8 Example of Wall Mounter PPE Cabinet

CHAPTER 5

CONCLUSION

5.1 Overall Conclusion

The results of this mixed methods case study showed how the physical environment, amenities and spaces in the pediatric patient room work zones affected RNs work efficiency and safety in terms of contact transmissions possibilities. To achieve that, the study identified the RNs care delivery activities, recorded RNs movement flows, and listed high contact surfaces in the PICU patient room based on data collected from the observations and interviews. The key implications are listed in Table 5-1. The findings provide evidence-based recommendations on improving efficiency by design and on enhancing infection prevention by minimizing opportunities for contact-based contamination transfer. This study informed future work zone design in the shared patient rooms of PICUs, and provided pre-design tools that evaluate the spatial environment in the patient room which assist designers to understand the end users' needs

Table 5-1 Summary of Key Implications

Topics	**Key Implications**
Work efficiency	• Heavy traffic flow between two sides of the patient bedside • Heavy traffic flow between the bedside and the disposal area

	• Large percentage of RNs' direct clinical patient care steps spent on checking and un-alarming vital sign monitors and IV monitors, which may not directly add value to RNs' work • Large percentage of RNs' indirect patient care steps spent on disposing trash, diapers, sharps, and PPE, which may not directly add value to RNs' work • RNs reported that they need to think about which supplies are needed before collecting them to avoid going back and forth between the supply closet and the patient bedside • RNs reported that they usually pile the trash around the bedside while delivering care and then gather all the trash together to take to the disposal area to avoid excessive walking • RNs reported that they need more walking space and work surfaces around the bedside to reduce inefficiency and hazards to patients' safety • RNs reported they need more work space for charting, medication preparation, lab work, and PPE storage.
Infection prevention: contact transmission	• Four highest possibilities of contact transmission surfaces: patient bed rails, IV pumps and poles, tubing and medical equipment around the bedside, and vital sign monitor screens. • Cubicle curtain and over-bed patient table are the fifth and sixth high contact surfaces in the patient room that are constantly touched by not only RNs but also families, visitors, and staff. • Current workflow adds RNs' contact frequencies with identified surfaces in the patient room

5.2 Limitations of Study

There were some limitations to this study. Since this is a case study of a PICU in an urban hospital, only four identical triple-patient rooms were observed and researched. It would be helpful to include single-patient rooms, or to include PICU triple-patient rooms in several other hospitals in the city to improve the generalizability of findings. This study was conducted over five consecutive weekdays in November in 2018 and did not include the morning rounding process, nurse shifting, and night nursing care; thus, other factors, such as time of the year, time of the day, time of the week, patient conditions, patient ages, the PICU operation and management, nurse training, education and RNs demographic backgrounds should be studied to increase the generalizability of the findings. Selection bias could also be a threat to the generalizability of the study, since all the participated nurses have more than 5 years of work experience in the current PICU.

In addition, since the researcher was the only observer in this study, time durations of clinical activities were not be able to be collected. This resulted in the failure of generating the value stream mapping to identify the medical care workflow waste. Thus, the findings could not provide insights to understand the clinical workflow and waste based on time and duration. Also, in order to avoid disrupting RNs daily work schedule and accommodating RNs limited time availability, only six nurses were included for the interviews. It would have been helpful to speak with all the observed nurses to understand their work process based on the behavioral mapping data, their opinions and insights of the current and ideal work environment.

5.3 Future Research Directions

The current study focuses mainly on the physical layout, amenities, and features interruptions on RNs workflow and HAIs. However, future research is required to understand how other factors like healthcare policy, management, and the social environment could moderate the relationships of the effects of the built environment on work efficiencies and infection prevention compliance. In particular, future research should consider the following:

1. The value stream mapping (VSM) is a useful and effective Lean system engineering tool in terms of understanding and identifying wastes in the workflow. Consider collecting time duration of each care delivery activity, since it is one of the essential components in VSM, to further explore RNs' medical care delivery work process, wasted activity, and time.
2. The policies, management, protocols, and education in the PICU concerning the built environment in the patient room should be understood and investigated as they could provide a systematic and comprehensive guide for work efficiency and infection prevention improvement.
3. The study should also be conducted in multiple hospitals' PICU patient rooms and include single-patient rooms to improve the generalizability of the findings.
4. A study or design consultant should further work with the PICU to provide detailed design solutions and constructions. After the design application, a pre-post intervention study and a post-occupancy evaluation study should be conducted to understand the effectiveness of the design recommendations on RNs work efficiency and contact infection prevention.

5. Connectivity analysis from Space Syntax should be considered to use for behavioral mapping data analysis when the future study deals with more than one site or more extensive observations data set.
6. The system engineering tools of “Use Cases” and “Originating Requirements” should be considered to use in the future study. Because the tools help to combine all data and recommendations in an organized way to ensure the requirement in a future patient room design could functionally support all users’ needs.
    a. Use cases are scenarios of how the system may be used by the users (Table 5-2). The content is similar to the clinical performance chart in the observation sheet of this study, but differently, it provides priority evaluation for each use case to elaborate the hierarchy. The priority level measures the importance of the system function. For example, the priority level in the current study determined by how many times the RN conducted the activity during the observation. The use cases could help designers to pay more attention on the issues that matter to the users and to understand their needs before providing solutions.
    b. Originating requirements table compiles all the functional requirements needed for the system and is derived based on the user’s use cases. For example, Table 5-3 provided holistic and explicit functional requirements for a PICU patient room by integrating all the findings and design recommendations from this study. This table could also be easily used as a facility design guideline for future PICU patient room designs.

Table 5-2 Use Cases in the PICU Triple-Patient Room

User: Registered Nurse			
Category	No.	Use Cases	Priority*
Unit-related Functions	1.	User prepares equipment	L
	2.	User transports patient	L
Infection Prevention Procedure	3.	User conducts hand hygiene	H
	4.	User gets hand soap / paper towel	L
	5.	User wears PPE	H
Direct Patient Clinical Care	6.	User continuous monitors patient vital signs	M
	7.	User observes patients to evaluate general condition	M
	8.	User prepares medication	L
	9.	User administrates medication	L
	10.	User checks the IV electronic readout	H
	11.	User untangles the IV lines	H
	12.	User suctions patients	L
	13.	User cleans patients	M
	14.	User comforts / plays with patient	L
Indirect Patient Care	15.	User picks up supplies/medication	H
	16.	User retrievals soiled supplies	H
	17.	User disposes sharps, supplies, PPE, diapers and trashes	H
Communication	18.	User communicates with other care providers	M
	19.	User communicates with family members	M
Sampling Blood	20.	User samples blood for lab studies	L
Documentation	21.	User documents patient EHR	M

*Priority is determined by RN conducted times: 0-14 times is low (L); 15-29 times is medium (M); 30 and more times is high (H)

Table 5-3 Originating Requirements for PICU Patient Room Design

Index	Originating Requirements	Function Name
OR.1	The system shall provide staff badge reader locks to supply closet and medication cabinet	Storage
OR.2	The system shall provide enough storage space to accommodate all medical supplies	Storage
OR.3	The system shall provide fridge storage for special medications	Storage
OR.4	The system shall have clear doors for medicine storages allowing direct view of interior content	Storage
OR.5	The system shall provide adjustable electrical task lightings in the preparation work zone	Lighting
OR.6	The system shall locate the medication preparation area visually connected to patient bed area	Preparation work zone
OR.7	The system shall provide 'from dirty to clean' layout in the preparation work zone	Preparation work zone
OR.8	The system shall provide enough clear space in front of the sink	Sink/ Sanitizer
OR.9	The system shall provide designated sink for staff use only	Sink/ Sanitizer

OR.10	The system shall provide a central vital sign monitor screen to present all three patients condition	Vital sign monitor
OR.11	The system shall provide a remote controller to un-alarm the vital sign monitors	Vital sign monitor
OR.12	The system shall provide portable devices (iPad) with access to patient HER and vital signs	Vital sign monitor
OR.13	The system shall provide enough work space for charting	Workstation
OR.14	The system shall provide storage space for RNs' personal belongings	Workstation
OR.15	The system shall provide adjustable task lights for charting	Lighting
OR.16	The system shall provide ergonomic task chairs with noise-reduced wheels	Workstation
OR.17	The system shall provide designated space for lab works, IV preparation, and medication preparation	Preparation work zone
OR.18	The system shall provide Workstation on Wheels (WOW) to provide work space for additional RNs.	Workstation
OR.19	The system shall provide mobile working cart as additional working surfaces	Workstation
OR.20	The mobile work cart shall include alcohol pre pads for patient cleaning	Workstation
OR.21	The mobile work cart shall include detachable small sharp trash bins and medical waste trash bins	Workstation
OR.22	The mobile work cart shall include storage area for additional PPE and supplies	Workstation
OR.23	The system shall provide antimicrobial sink with automatic faucet	Sink/ Sanitizer
OR.24	The system shall provide at least 2 hand sanitizers in the preparation zone and 1 hand sanitizer in the bedside work zone	Sink/ Sanitizer
OR.25	The system shall provide hand soap less than 8" from the center of the sink	Sink/ Sanitizer
OR.26	The system shall provide hand dryer less than 10" from the center of the sink	Sink/ Sanitizer
OR.27	The system shall provide designated PPE storage locations in the preparation zone and the bedside work zone	PPE
OR.28	The system shall provide PPE organizer that large enough to store gloves, masks, and gowns	PPE
OR.29	The system shall provide PPE adjacent to hand sanitizers / sink	PPE
OR.30	The system shall provide larger space around the patient bedside to maintain RNs' working clearance	Bedside work zone
OR.31	The system shall provide enough space for both the mobile work cart and patient overbed table	Bedside work zone
OR.32	The system shall provide adjustable overbed artificial lighting	Lighting
OR.33	The system shall provide walking space behind the bedhead	Bedside work zone
OR.34	The system shall provide sharp containers, garbage receptacles, and contaminated supply disposal units near the point of care and easily accessible locations	Disposal area
OR.35	The system shall consider providing ceiling mounted flexible booms for the power, storage and vital sign monitor display in the bedside work zone	Bedside work zone

OR.36	The system shall apply antimicrobial material on the identified high-contact surfaces	Material

7. The Integration Definition for Function Modeling (IDEF0) tool could be considered to use in the future study to have deeper understanding of current nurses' workflow and the required structure and functional needs of the spatial environment. This system engineering tool could visually present the relationship between functions through the sequential input and output in the diagram. Usually, several levels are needed to fully represent one function of the system. Figure 5-1 shows an example of a second level in the IDEF0 for a patient room system project to understand the function of "nurse delivering care to the patient."

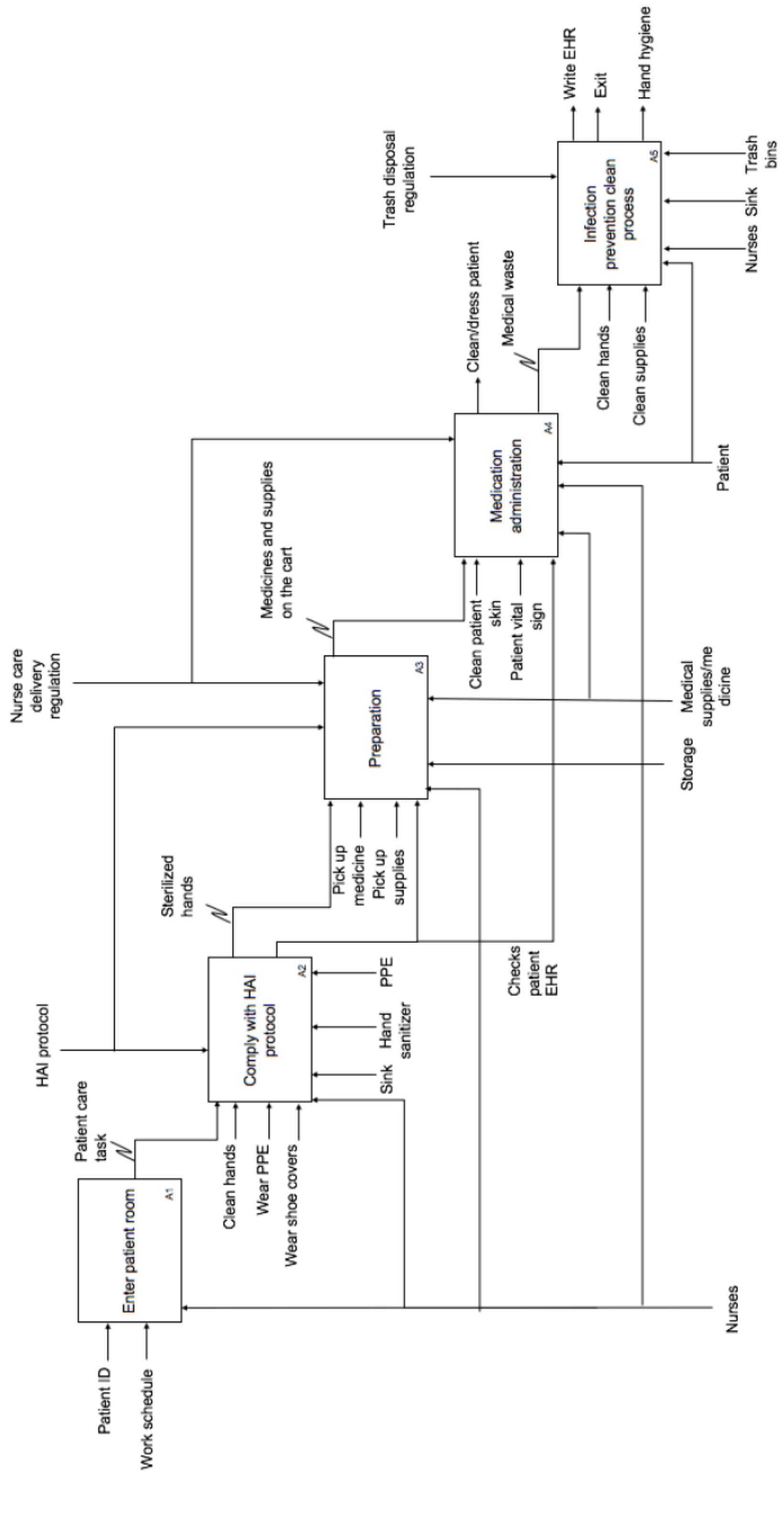


Figure 5-1 Example of IDEF0 Diagram

APPENDICES

Appendix A: IRB Approval

Cornell University
Office of
Research Integrity and Assurance

East Hill Office Building, Suite 320
395 Pine Tree Road
Ithaca, NY 14850
p. 607-254-5162
f. 607-255-0758
www.irb.cornell.edu

Institutional Review Board for Human Participants

NOTICE OF EXPEDITED APPROVAL

To:	Yuqian Lu
From:	Andrew Willford, IRB Chairperson
Protocol ID#:	1808008183
Protocol Title:	Future model for Pediatric ICU (PICU) patient room: Optimize care delivery in terms of staff efficiency by design
Approval Date:	August 24, 2018
Expiration Date:	None

Cornell University's Institutional Review Board for Human Participants (IRB) has reviewed and approved the inclusion of human participants in the research activities described in the protocol referenced above. This approval shall remain in effect for the duration of the study.

The following personnel are approved to perform research activities on this protocol:

- Yuqian Lu
- Rana Zadeh

This approval by the IRB means that human participants can be included in this research. However, there may be additional university and local policies that apply before research activities can begin under this protocol. It is the investigator's responsibility to ensure these requirements are also met.

Please note the following important conditions of approval for this study:

1. All consent forms, records of study participation, and other consent materials **must** be held by the investigator for **five years** after the close of the study.
2. Investigators must submit to the IRB any **proposed amendment** to the study protocol, consent forms, interviews, recruiting strategies, and other materials. Investigators may not use these materials with human participants until receipt of written IRB approval for the amendment. For information about study amendment procedures and access to the Amendments application form, please refer to the IRB website: http://www.irb.cornell.edu/forms.
3. Investigators must promptly report to the IRB any **unexpected events** involving human participants. The definition of prompt reporting depends upon the seriousness of the unexpected event. For guidance on recognizing, defining, and reporting unexpected events to the IRB, please refer to the IRB website: http://www.irb.cornell.edu/policy.

Figure A-1 IRB Approval Letter

Appendix B: Behavioral Observation Sheet

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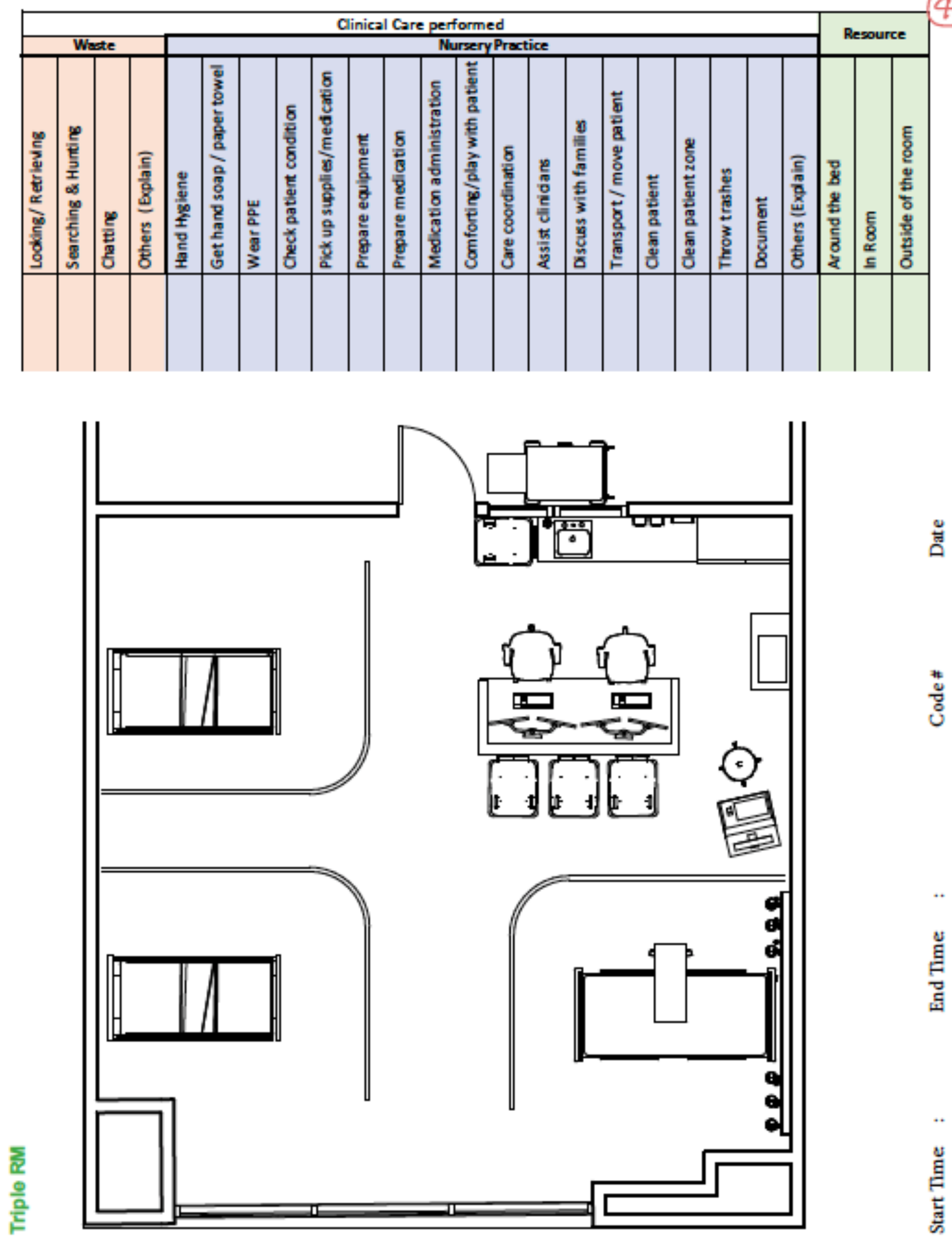
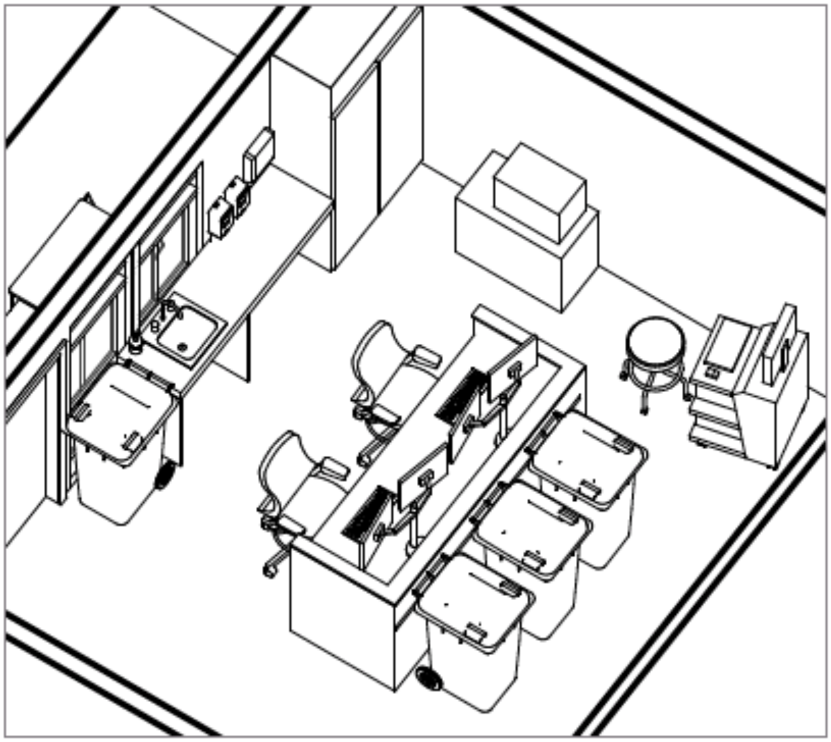
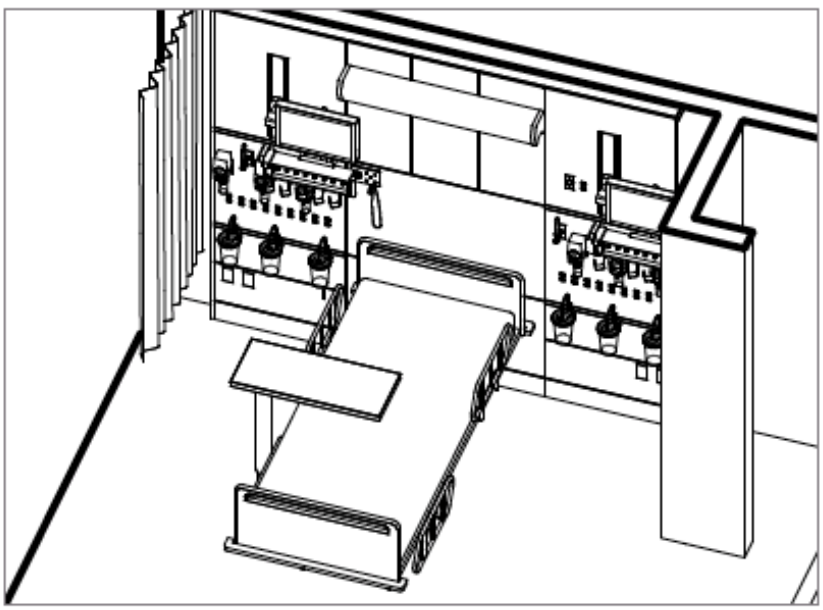


Figure B-1 Observation Sheet front





Triple RM

Figure B-2 Observation Sheet Back

Appendix C: Interview Script

Welcome! My Name is Yuqian Lu, Master of Arts Student from design environmental analysis Cornell University. I am requesting that you participate in a research study because you are a staff member in the Pediatric ICU (PICU) at the Weill Cornell New York Presbyterian Hospital.

The goal of my thesis is to identify design elements in the PICU patient room to help staff members when they do their work reduce burden for safety and efficiency. My research has three specific aims: 1) understand the role currently the patient room plays in your work. 2) Identify the desired patient room design to help facilitate care, (e.g. the form and location of equipment, supplies, materials and interiors). 3) Create a patient room model that accommodates desired care delivery and support staff members.

The interview will take about 15-30 mins depends on the availability of participants. All participants will be provided with pens and papers to write and draw their responses. I have three questions want to ask and learn your thoughts, opinions and experiences. We will have at least 5 minutes for each question.

1. Could you please let me know what sort of patient care activities you do in the patient room?
2. In these activities, how do you interact with the physical interior environment, equipment, and immunities (For example, when you need to reach the equipment while doing the bedside care, are they accessible and at the location you need? Does the physical environment support your posture or causes strain?

Do the patient room layout and equipment locations require additional steps or are at optimum position?)

3. What would a future ideal Pediatric Intensive Care Unit patient room look like? If you could redesign or rearrange the room from bottom up, what would it be? (paper and pencil will be provided for draw or write when need)

Appendix D: Observation Schedule

Table D-1 Observation Schedule

Date	**Location**	**Start Time**	**End Time**
Nov. 12th, 2018	Patient room 403	1200pm	0700pm
Nov. 13th, 2018	Patient room 401	1100am	0600pm
Nov. 14th, 2018	Patient room 408	0100pm	0600pm
Nov. 15th, 2018	Patient room 403	1100am	0600pm
Nov. 16th, 2018	Patient room 401	1130am	0530pm

Appendix E: Samples of Behavioral Observation Sheet Data

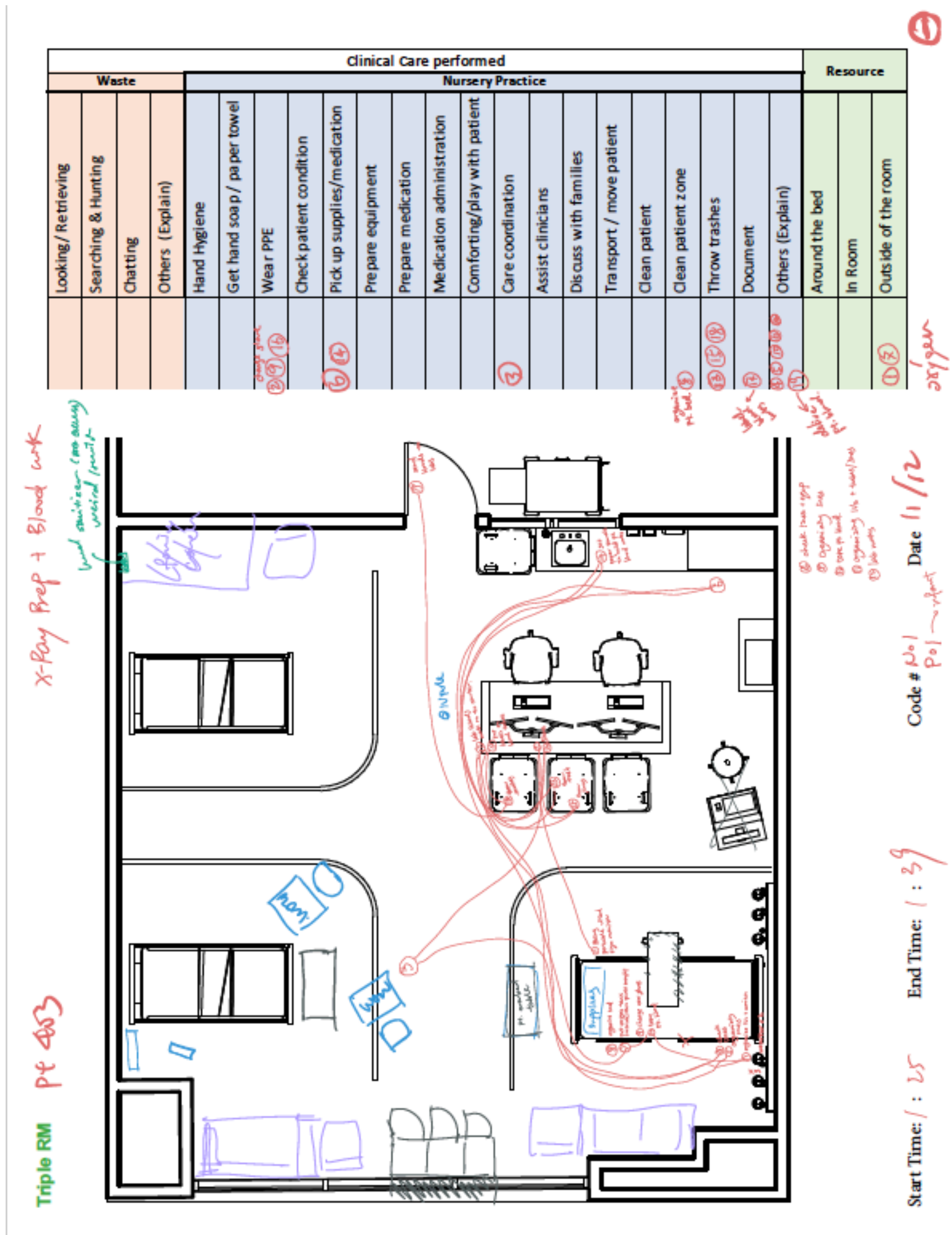
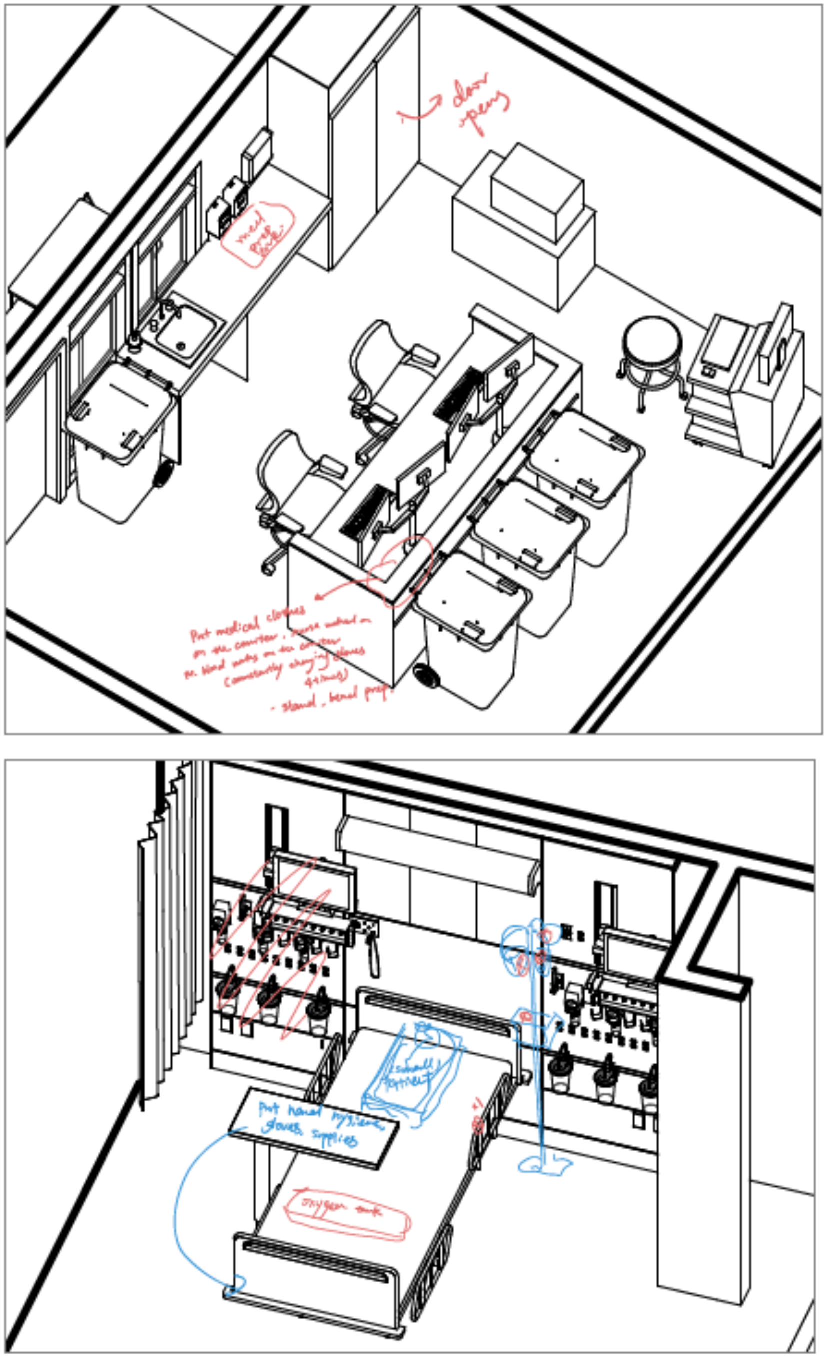


Figure E-1 Observation Sheet Data 1-1



Triple RM

Figure E-2 Observation Sheet Data 1-2

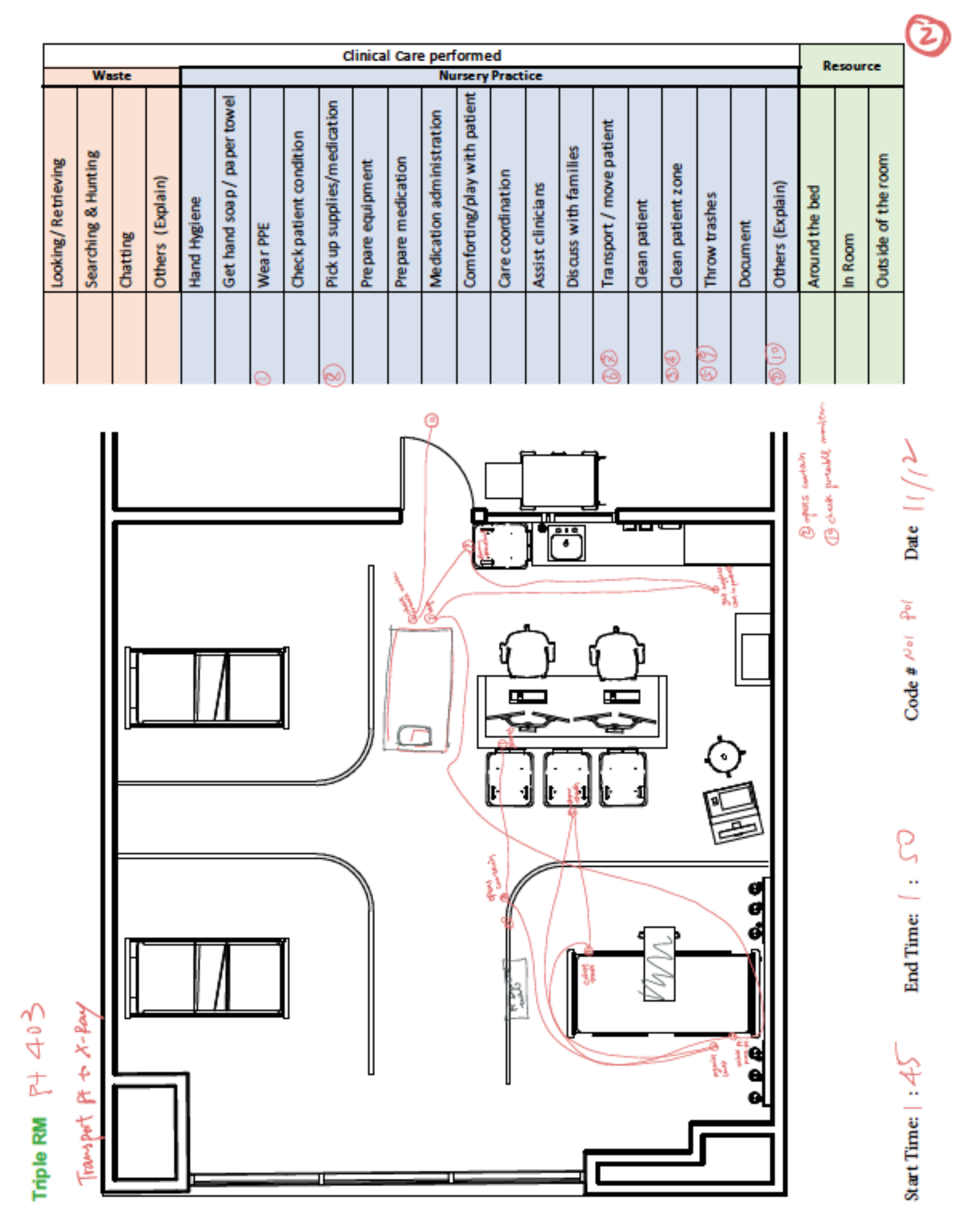
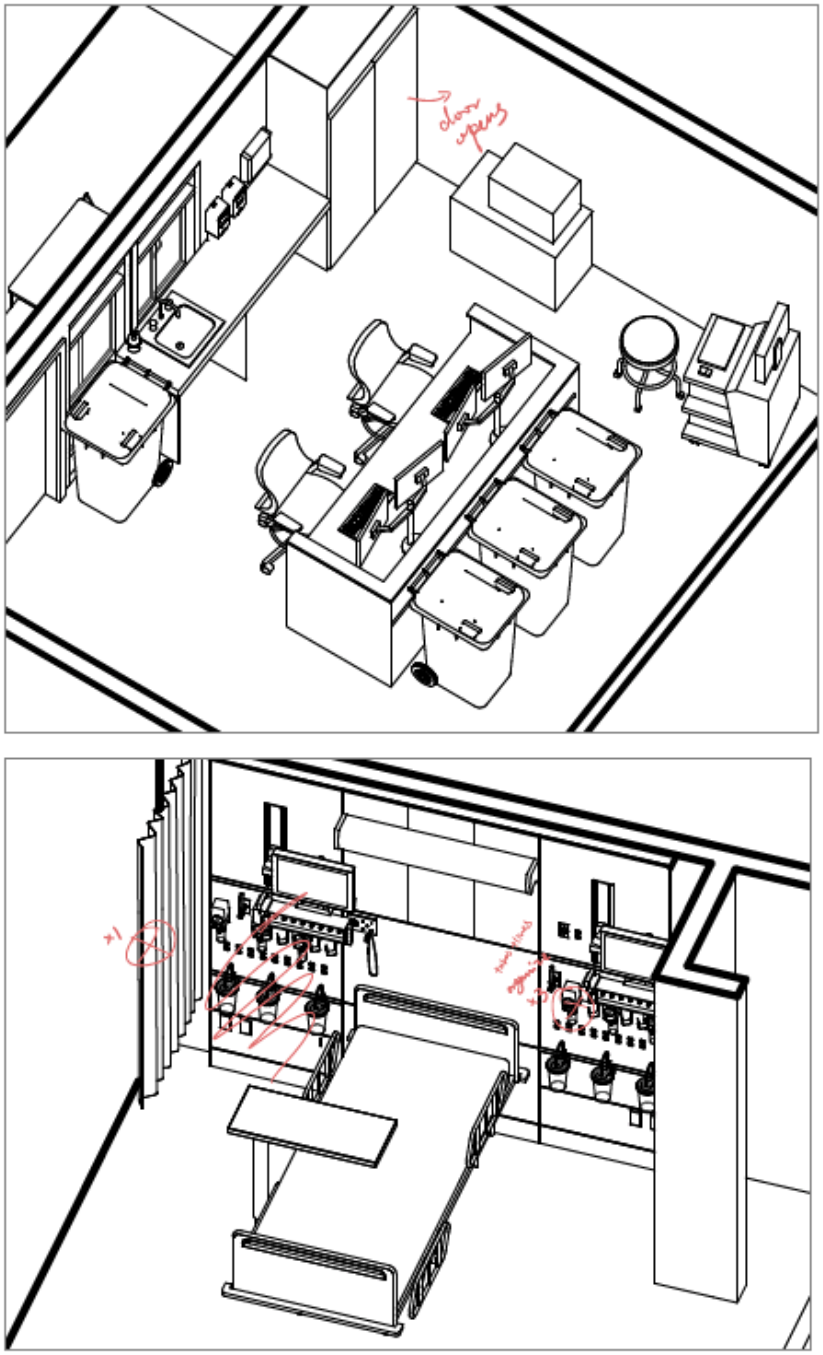


Figure E-3 Observation Sheet Data 2-1



Triple RM

Figure E-4 Observation Sheet Data 2-2

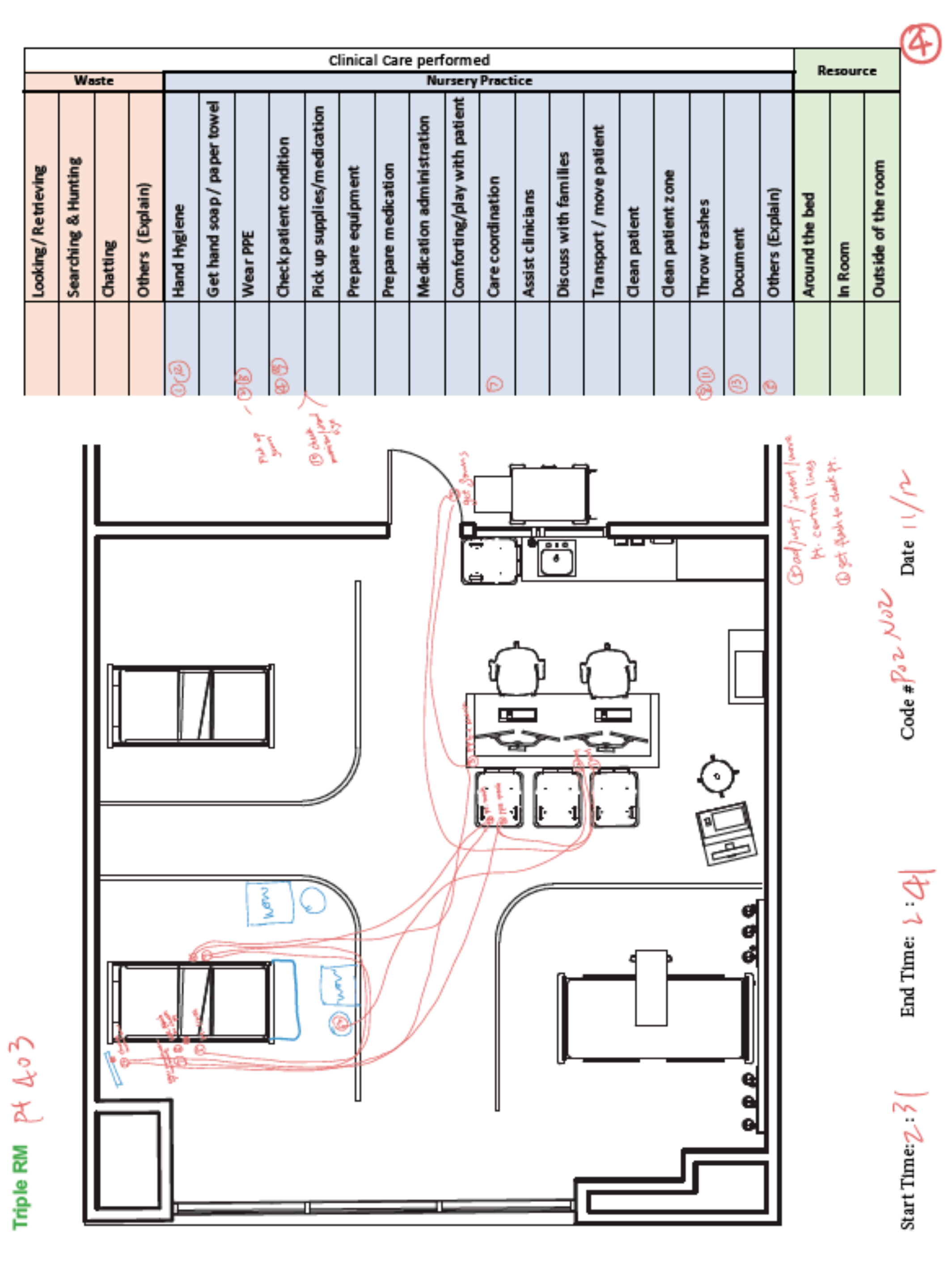
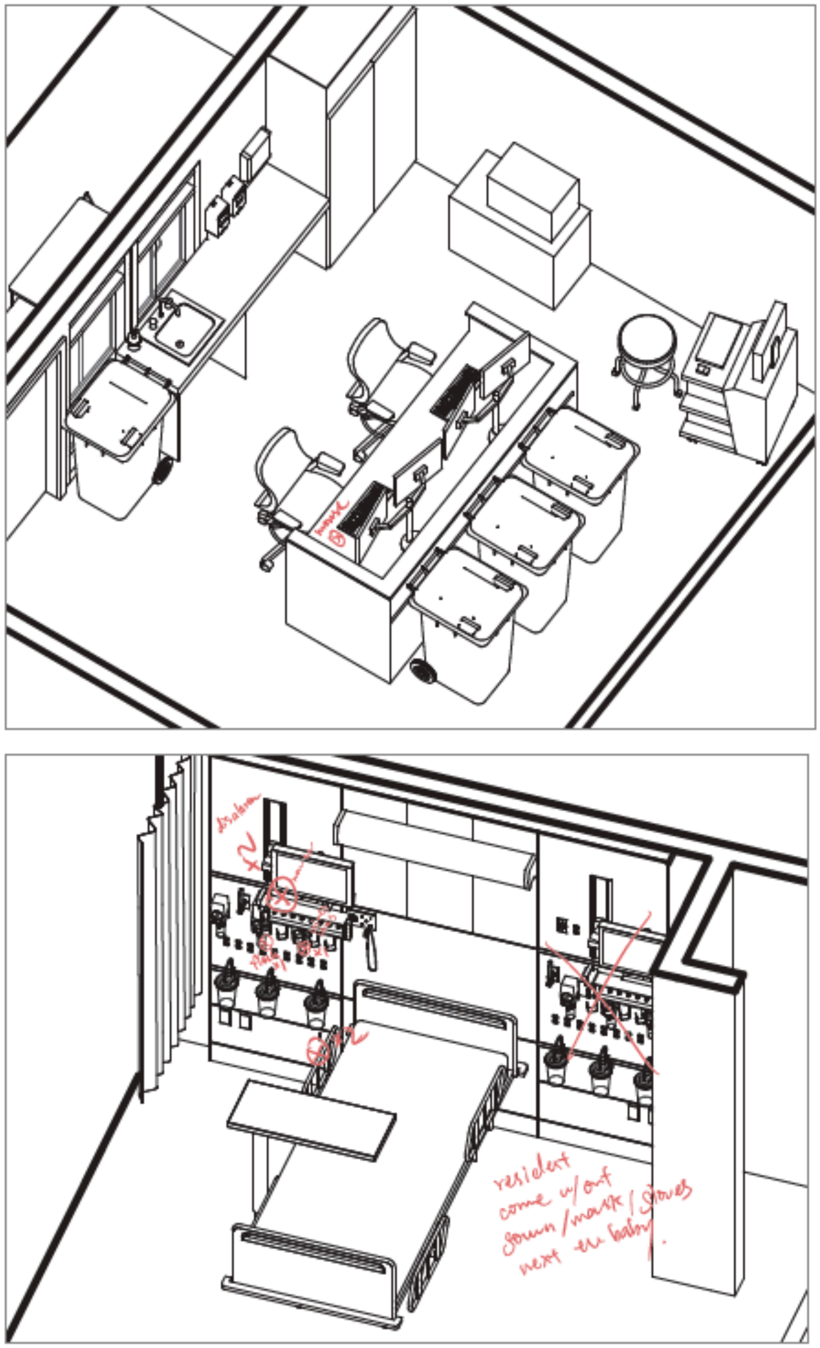


Figure E-5 Observation Sheet Data 3-1



Triple RM

Figure E-6 Observation Sheet Data 3-2

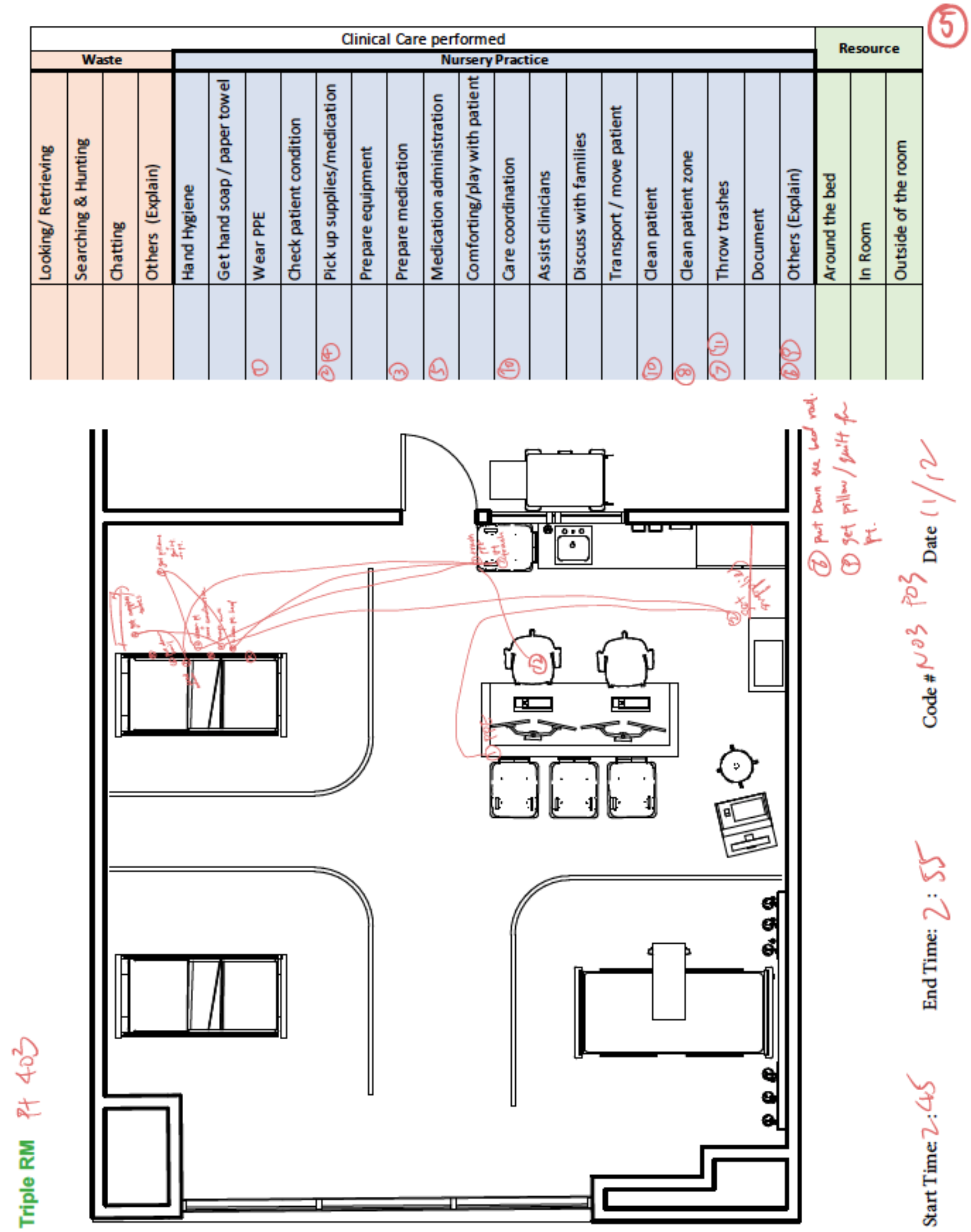
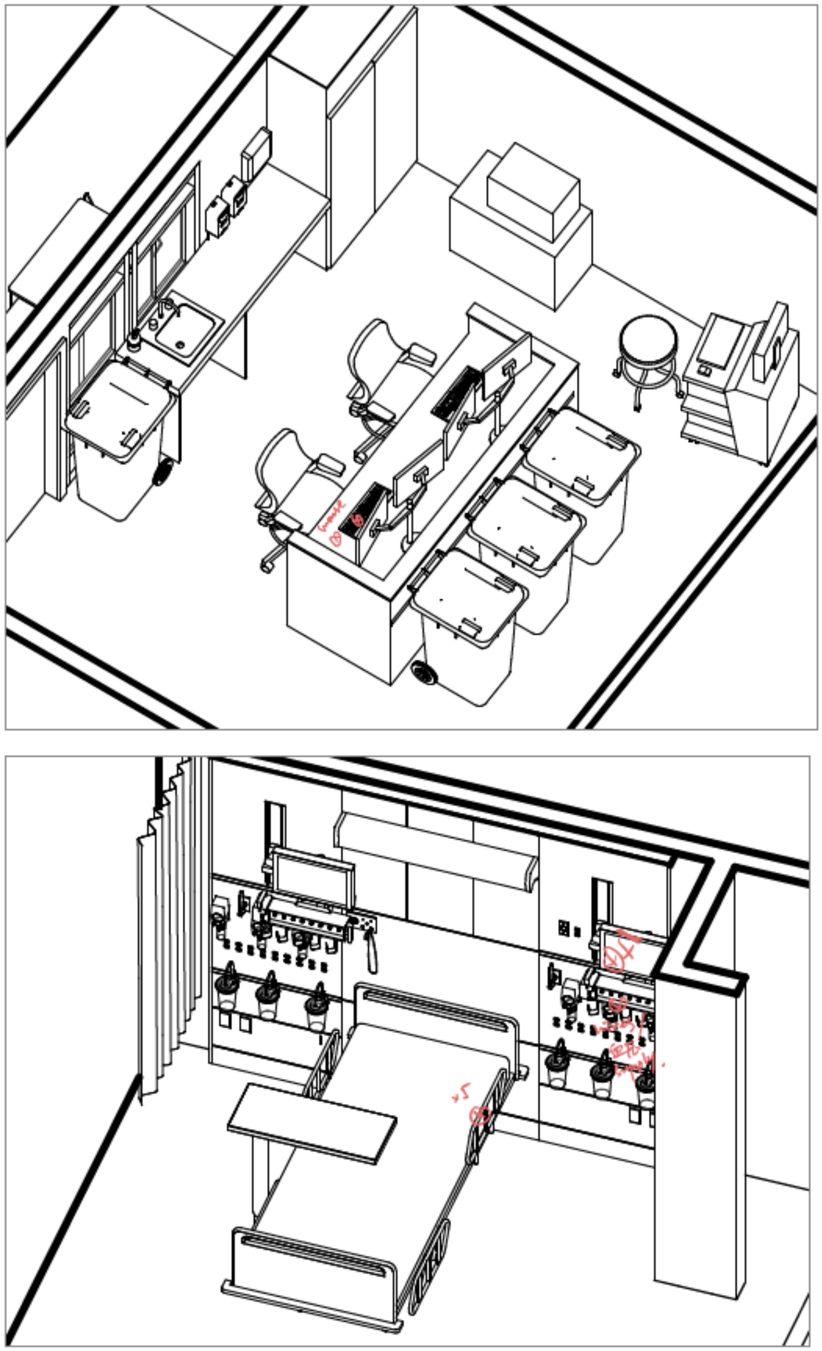


Figure E-7 Observation Sheet Data 4-1



Triple RM

Figure E-8 Observation Sheet Data 4-2

Appendix F: Sample of Interview Transcription Data

Table F-1 Samples of Interview Transcription

Interview Content			
	Current condition (good)	**Current condition (bad)**	**Future patient room**
1. Nurse Station	I like the nursing station is in the room, and we can see all three patients at any given time no matter what multi-bedded room you are in	I do not have comments to the work space, but I do hate though everything is being stuck with these wires…”"	have a space just for computer charting here, and then others somewhere else
	it's great that the nursing station is in the room… it is so easy to get to the patient bedside... I feel if they have a glass door, that would definitely hinder the care	we used to have the desk space in an L shape....so you had more counter space to do things, we also do not have these.	have individual nursing stations at the bedside... as a lot of patients require one to one care
		… (Continuous)	… (Continuous)

2. Supply retrieval / disposal	most supplies we need are in here [the closet]	The problem is that there's a disconnect because infection control doesn't even want these [PPE] here. They want me to go to that yellow cart in the hall. But you see how often I make patient contact. So they want you to go to that yellow part in the hall. Get your gown. get your mask, get your gloves then come to your patient and then take it off. Then clean your hands and then sit down. But I do that more than one time in an hour and I'm here for twelve hours. So we put them here to make it easier for us. But I don't necessarily think that they would condone us keeping them at the bedside.	the private room is easier because there is a workplace, you just put everything and go in, and there is work tablespace, which is nice…
	you do not need everything next to the patient... you can walk to the closet and wipe you patient	I do not think you technically could do it [put the gowns on the top of the nurse station], but will you go outside to the yellow cart every time you need gown? I do not think so.	when they empty the garbage, they make the loudest noise…I know some units actually built the garbage bins into the walls from the outside of the room… you filled the garbage inside the room and empty them outside the room
		… (Continuous)	… (Continuous)
3. Med preparation	we have our counter space here, never had an issue with med preparation	lab works is done everywhere	So that (hook on the wall) is added by our unit consult for people that was complaining there was no prep IV fluid… that is an easy and cheap budget solution…
		This [med preparation] counter gets cluttered	You need task light for the med preparation area.
		… (Continuous)	… (Continuous)

4. Sink		“[the centralized sink location] so it's defeats the purpose because we still have random people coming and going over here. So. They're passing by my preparation area. Yeah. It's not ideal for sure.	if you change IV fluid, and you are the only person, so you have to somehow hold on to it without dropping it and everything pouring out, and that would so easy [if you have sinks for each patient] because you could just literally throw it to the sink right next to us. or you could wash your hands right away.
		… (Continuous)	… (Continuous)
5. Bedside Work zone	the layout is not bad, the patient has their own space per se...I like the closets are now central.... because put them in the central space providing a little bit more bed space	So I put myself in danger trying to plug things in and take them out like where I could trip where I could get caught in my patients shooting and then harm them.	we need a way to have a power strip or like some source of power that is centralized on the floor
		The biggest problem is the three-bedded room	there is walking space behind the bed, where even machines can be pushed and angled there, and you have access to the patients from both sides, but you can get to the machines on both sides but out of your way
		… (Continuous)	… (Continuous)
6. Vital Sign Monitor		curtain closed, you cannot see the patients’ monitor	So there should be a central monitor just like there's a computer right here where I can see all three monitors in the room so that people can still have privacy that I can still observe.”

		a lot of times the alarm beeps, so every time you either have to walk over there, or we have these remotes, these remotes always do not work, a lot of them are broken... so theoretical can un-alarm it... but you have to look up and see the vital signs... it is pretty loud beeps	So either there needs to be a remoter the same way that the TV has a remote like the monitor remote should also be available to the nurse or to the doctor or to anybody so that you can access things on the monitor and silence things on the monitor while you're standing there without bringing this over
			… (Continuous)

Appendix G: Sample of Clinical Performance Chart Data

	Start time	End time	Room #	Date	PT #	RN #		Nursing Practice																						Resource retrieval locations			Task
								Unit-related functions		Infection prevention procedure			Direct clinical patient care									Indirect patient care			Communication		Documentation	Sampling blood for lab studies	Others				
								Unit-related functions							Medication administration		Check Iv status																
								Prepare equipment	Transport patient	Hand Hygiene	Get hand soap / paper towel	Wear PPE	Continuousl monitoring of vital signs	observing the patient to evaluate general condition	Prepare medication	Medication administration	Check the IV electronic rea	Untangling IV lines	Suction patient	Clean patient	Comfort/play with patient	Pick up supplies/medication	Retrieval soiled supplies	Disposal of sharps, supplies, PPE, diaper & trashes	Communicate with other care providers	Communicate with family members	Documentation	Sampling blood for lab studies	Others (Explain)	Around the bedside	In Room (supply closet, nurse workstatio	Outside of the room (medication room, tube system behind clerk's desk)	
01	13:25	1:50	403	12-Nov	01	01																											Blood Work/Lab work
							1															1									1		
							2					2																					
							3																		3								
							4										4																
							5											5															
							6															6									6		
							7	7																									
							8																8										
							9					9																					
							10																					10					(take pt. blood)
							11											11															
							12																					12					
							13																	13									
							14															14											(paper towel for blood work)
							15																	15									
							16					16																					
							17																				17						(blood work label)
							18																	18									
							19																					19				19	(deliver pt. blood work)
02	1:45	1:50	403	12-Nov	01	01																											Transport patient
							1					1																					
							2																						2				open curtain
							3											3															
							4																4										
							5																	5									
							6		6																								
							7															7									7		put in nurse's pocket
							8																	8									
							9						9																				portable monitor

Figure G-1 Clinical Performance Chart Data

03	14:15	14:28	403	12-Nov	02	02																											*P02: contact isolation. Task: regularly check patient
							1					1																					gown, gloves
							2					2																					mask
							3							3																		
							4																	4								
							5											5													(put down the rail) - clean patient
							6											6													(put up the rail) - clean patient
							7									7															
							8														8										
							9															9									
							10							10																		
							11														11										(organize the table)
							12						12																			
							13															13									throw PPE
							14			14																						
							15																		15							
04	14:31	14:41	403	12-Nov	02	02																											*P02: contact isolationn; Task: regularly check patient
							1			1																						
							2					2																					gown
							3					3																					gloves, mask
							4							4																		
							5										5															
							6							6																		use flash to check patient
							7																7								
							8															8									
							9							9																		
							10						10																			
							11															11									
							12			12																						
							13																		13							
05	14:45	14:55	403	12-Nov	03	03																											Administrate medication
							1					1																					
							2														2									2		
							3								3																	
							4														4								4			
							5									5																
							6															6										put down the bed rail - organize pt zone
							7																7									
							8															8										
							9															9										put up the bed rail - organize pt zone
							10											10					10								
							11																11									

Figure G-2 Clinical Performance Chart Data

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